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# Dr. Boerhaave's Academical Lectures

ONTHE

## Theory of PHYSIC.

BEING

A Genuine Translation of his

### INSTITUTES

AND

Explanatory COMMENT,

Collated and adjusted to each other, as they were dictated to his STUDENTS at the University of Leyden.

### VOL. III.

Containing the Structure and Action of the Spleen, Omentum, Liver, Kidneys, Bladder, Muscles and Skin; with the Nature of Sweat, Perspiration and Nutrition.

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### The Action of the SPLEEN.

HE Seat of the Spleen, with its Vicinity to the coeliac Artery, and its Office with respect to the Liver, as also the particular Course of its Humours, requires of us in the next place to treat first of that Viscus.

§. 313. It is fituated in the left Hypochondrium, hangs pendulous 2 from the Diaphragm, and adhering to the left Kidney and to the Omentum, it is by this last in a manner connected to the Stomach; whence it easily permits itself to be variously pressed 3, and agitated upwards and downwards, by the Motion of the Diaphragm and abdominal Muscles, (§. 86.)

This is the natural Seat of the Spleen; tho there are three or four Instances upon Record, in which the Viscera being reversed, the Spleen has been found seated in the right Hypochondrium.

Not fix'd, but at liberty on all Sides; fo that it may be variously agitated and pressed up and down with the Diaphragm, more especially in Brutes.

The whole Cavity or Sack of the Abdomen is extremely full, and is contracted against all the Viscera with a considerable Force by the Muscles B

placed round: but this force is alternate and unequable, and therefore the abdominal Viscera suffer an alternate and unequal Pressure. In Inspiration all those Viscera are pressed downward with a confiderable Force by the incumbent Diaphragm; but in Expiration, on the contrary, they are preffed upward and backward with no less Force by the Muscles of the Abdomen, which thrust the Peritonæum towards the back. But how great the Force is with which the abdominal Muscles operate, Sennertus demonstrates by instancing a Student, who was wounded through the Diaphragm by Puncture with a Sword: for though the Wound was but small, yet the Stomach was obliged to ascend into the Thorax through the dilated Wound, from the perpetual Contraction of the abdominal Muscles, so as to kill the Patient after the most severe Pains. But besides the Force of the Muscles here consider'd, the Stomach also presses upon the Spleen when distended with Aliments, and by that means thrusts it against the lateral Arch of the Peritonæum. Hence the Spleen appears altogether like a Spunge full of Blood, confined in a ftrong Membrane, which receives the strong Pressures from the ambient Parts by which the venal Blood is pressed out of the Spleen towards the Liver. For that the Passage of the venal Blood of the Spleen towards the Liver is flow and difficult, Men of Letters, who lead fedentary Lives, experience to their Detriment. For when these retire to rest in Solitude, that the Mind may perform its Operations more diffinctly, if they neglect to promote the Course of the Blood by proper Exercise of Body, it becomes accumulated in the Veins of the Spleen, ftagnates and thickens fo as to prove a Source to an infinite Number of other Difeases; from whence Weakness.

ness, Inflations, and all the various Symptoms which appear under the Denomination of hypochondriacal Disorders. In short, the Spleen stands so much in need of this alternate Pressure to forward the Course of its Blood, that without it, it must stagnate, and be scarce capable of performing its Circulation.

§. 314. It receives the pure arterial Blood foon after it has been expelled from the Heart, by the first considerable Artery which arises beneath the Diaphragm, namely, the coeliac Artery: for whilst the first Branch of this Artery sends out this to the Spleen, the third? Branch often sends out three others to it; or sometimes this Artery arises from the Aorta in such a manner, as to send its Branches to the Liver, Pancreas, Duodenum, and Stomach, which receive their Arteries from the same Trunk with the Spleen; whence it appears that the Blood distributed to all those Parts is of the same Nature.

All the Blood of the Spleen is derived from the coeliac Arterery, which is the very first Branch that arises from the Aorta below the Diaphragm. The same Blood was but the moment before in the Heart itself, since when no kind of Humour was separated. It is true, the Blood of the descending Aorta is heavier than that which ascends, but yet it does not deserve the Name of sæculent Blood, or atrabilis.

This is not constantly observed in Nature; and sometimes the Branch from the coeliac Trunk is single; and sometimes there are two or three Branches, as in the emulgent Arteries.

B 2

§. 315. These Arteries of the Spleen which are large, and a great deal bigger i than those of the Liver, having enter'd into its Body, are immediately distributed throughout the whole Mass of the Spleen, dividing into an infinite Number of small Branches 2, whose Extremities are collected and spent in Bunches of very minute Ducts, which have in some measure the Appearance of small Glands 3; and in this manner do the splenic Arteries vanish in every Part about the Extremities of the corresponding Veins.

The splenic Arteries are at least fix times larger than the hepatic; but the Weight of the Spleen is scarce a sourth Part to that of the Liver: and therefore, in a given time, twenty-four times as much Blood will pass through the Arteries of the Spleen, as through those of the Liver. And the Quantity of this Blood is still larger, as the Spleen confifts entirely of Vessels without any Fat or Muscle in its Composition; from whence it feems to be manifest, that the Liver receives its arterial Blood for its own proper Use, but that the Spleen does not receive all that Blood for its felf, but for the common Use of some other Parts. But so soon as the splenic Artery has enter'd the Substance of that Viscus, it deposits its muscular Coat, as we observed of the carotid Artery; which muscular Coat serves to compose the proper Tunic itself of the Spleen, which is white, compact, and thick. And betwixt this Coat and the outermost and common Tunick derived from the Peritonæum, there are distributed small Vessels and lymphatic Ducts. But the Artery divides itself into two Classes, one of which serves for the Nutrition of the Spleen, having lymphatic Veins formed for the venal System: and the other Class, which conveys the Blood for some common Use. disappearing in very small Branches; many of which are formed into small Bundles or Bunches, fo as to refemble a round or obtuse Body. From hence Ruyleb confesses, that he imagined the Spleen to have the fame glandular Fabric with many of the other Glands.

The Artery is distributed in large Branches through the whole Spleen, in every Part of which they feem to terminate in little Heaps, as far as our Senses are capable of distinguishing: for if the Spleen be examined after it has been dried of itself, you can distinguish nothing in the Extremities of the Vessels; but if it is first filled by the Ruyschian Art of injecting, then the whole Mass of it seems to be converted into the ceraceous Injection.

3 Ruysch formerly confessed in more Places than one of his Writings, that he discovered small Glands in the Spleen; a while afterwards he afferted that he could difcern small Bodies, but of an unknown Fabric; and again, after this he testifies that he can find nothing else but Vessels; and this notwithstanding he was a Man of great Veracity, averse to Reasoning or Hypothesis, but a simple

Historian or Relator of Facts.

§. 316. The comparative 1 Anatomy of this Viscus, as it appears in Men, Oxen, Sheep, Moles, Hedgehogs 2; the morbid Disposition of it in dead Bodies, in which the Spleen is beset with petrified 3 Tubercles, and the Appearance observable in a macerated 4 Spleen;

all render it probable that the small Arteries (315.) degenerate into a glandular Fabric (242 to 254.)

Viscera through all the Species of Animals and Insects, whose Fabric he could not any way discover in the human Body; in order that he might discover in one Species what was concealed in the other; and he found that all Animals had both a Liver and Spleen, the Liver being larger in proportion as the Animal is colder.

In this Animal the Spleen, as well as the other Viscera, is composed of many distinct Lobes like

Glands.

Not only Malpighi, but also many other Anatomists have observed human Spleens in chronical Diseases to be filled internally with round petrified Bodies, or else filled with some hard Matter, which seems to be situated without the Limits of the Arteries or Veins. There is therefore in the Spleen tertain Cavities into which that morbid Matter is deposited: for it does not seem probable that those Cavities were made in the Disease, but that they were rather so small as to be invisible in their natural State, but by Distention with impacted Humours, they become at length conspicuous to the naked Eye.

The Spleen being macerated in warm Water, drinks in that Water by its lymphatic Vessels, which are therefore easily demonstrated by this simple Contrivance; and if it be afterwards freed from its Integuments, its internal Fabric will appear very much like the glutinous Silk which has been lately spun by the Worm, and there will appear a great Number of little Bladders full of Water within it's Substance. But these Bladders differ

from

from Glands, inasmuch as they are destitute of excretory Ducts, at least any that could be discovered by the greatest Industry of Malpighi. But it is sufficient for our Purpose, that we find an intermediate or thin Substance betwixt the Arteries and Veins of the Spleen, either of a glandular or vesticular Fabric, the Appearance of which is not denied even by Ruysch himself.

§. 317. But as an artificial Injection of the Vessels in this Viscus demonstrates a direct or ready Passage 1 from the Arteries into the Veins, therefore it would seem that all the Extremities of the splenic Arteries do not terminate in the same manner, but that they considerably differ 2 in their Extremities from each other; which Difference however has not yet been distinctly exhibited to the Eye by any Artifice 3 hitherto known, chiefly because of the great Tenderness or Friability of this soft Viscus.

For Water or even ceraceous Matter being injected by the splenic Artery, very easily returns through the splenic Veins, and the reverse; as is evident from the Experiments of Swammerdam and Ruysch.

So that some of the Arteries return their Blood immediately into the Veins, while others pour it first into an intermediate Cavity or Cell; namely, into the Vesicles or small glandular Corpuscles before observed.

For even Ruysch himself, nor any other Anatomist, could ever entirely demonstrate the Fabric of the Spleen. For even the very Injection itself, from the Softness or Perviousness of the Viscus, B 4 confounds

confounds the Eyes and Examination of the Anatomist; infomuch that a Spleen which has been the most happily injected, being cut through the Middle, appears as it were one continued Mass of Wax, so that one cannot distinguish the different Kinds of Vessels; and if the external Coats are taken off, the foft Viscus dissolves or unravels itself. fo as to fluctuate almost in the manner of the Brain which has been macerated; by which means every thing is confused, in such a manner that I have not yet been able to determine my Judgment with Certainty concerning the Fabric of the Spleen, which is more difficult to fearch well into than any other Viscus. If you macerate a Spleen uninjected in Water for some time, as was formerly done by Vanborne, but latterly by Ruysch, all the fleshy Substance of the Spleen will then be gradually diffolved barely by Putrefaction, and a gentle Concustion. If Mercury is injected into the Spleen after the manner of Nucke, it then turns into a hollow Bag full of Quickfilver. If again you inflate Wind by the Artery into a Spleen whose Blood has been washed out, and its Vein tied, after drying and cutting it open, it appears to be nothing else but Fibers.

S. 318. It is evident at least that the Structure of this Viscus is much the same with that observed in all other Parts, wherein a Secretion is performed, and therefore it would seem that the same Action must be also performed here: but yet there is no common excretory Duct 2 coming from the Spleen; and the Lymphatics 3 which are found in it, run only betwirt the two Membranes in the Spleen, and also in some Places at a Distance from the splenic

Body,

splenic Artery, being sewer in Man than in other Animals; nor do they enter into the inner Substance of the Spleen, nor arise from the Extremities of these Vessels, which serve for the Nutrition of the Body of the Spleen.

- Namely, there is here an Artery importing Blood, which is also accompanied with an exporting Vein; and there is also a third, something which is neither Artery nor Vein, but which receives the Blood and retains it for some time. Hence therefore it may not be unreasonable to conclude, that some kind of Secretion is made in the Spleen; since the same Fabric being given, as the same Cause, ought necessarily to produce the same Effect.
- From the internal Side of the Spleen, no Vefsel comes out besides the Vein; but a Vein is no excretory Duct, fince it returns nothing but the superfluous Blood towards the Heart; and in every fecretory Organ there is a distinct Vessel besides a Vein, carrying a distinct Humour, prepared by the Organ, for the Use of its self and of the whole Thus in the Kidney, besides the renal Arteries and Veins which correspond to those Arteries, there is an excretory Duct called the Ureter. In the Pancreas, besides the Arteries ramified from the Cœliac, and the Veins corresponding to them, there is also a salival Duct, which carries a thin Liquor to the intestinum Duodenum; and this is the common Fabric of the Glands and Viscera. from which the Spleen only is excepted, as having no peculiar third kind of Vessel.

It is no difficult Matter to refute the Theory of Glisson, who imagined the Spleen to be formed to draw a large Quantity of Lymph from the Blood. For the Lymph flows back from every Part of the

Body, whether any Secretions be made in it or not. Thus there are numerous Lymphatics in the Liver and Kidneys, which are fecretory Organs, and also in the Lungs which is no fecretory Organ; which Vessels have been demonstrated and represented by Nucke, whose Preparations of the lymphatic Veins taken out of the Body and artfully preserved, I have frequently viewed with much Pleasure. Office of the lymphatic Vessels is common to the whole Body, and does not relate to the Fabric of any particular Part. It is indeed true, that every least Particle stands in need of being nourished. but nothing can be brought for Nutrition except through the fanguiferous Arteries, (§. 261.) which are the larger Series of the smaller Vessels; (§. 226.) and therefore there is a Necessity for pellucid Arteries which exclude the red Blood by their Smalness, in order to convey Serum, Lymph, and more thin Juices for the Nutrition of those Parts which do not admit the red Blood. (§. 245, 261.) But Arteries have always their corresponding Veins, to return those Juices again to the Heart, which have not been confumed in Nutrition; and these are the Veins which we call lymphatic Vessels; which being every where feated, the particular Use of the Spleen cannot be therefore restrained to the lymphatic Veffels.

§. 319. Since therefore comparative Anatomy teaches us that the same Structure of this Viscus is observable in most Brutes; therefore the fame Fabric may also take Place in the human Spleen, though it cannot be there so easily demonstrated to the Eye. But such however is the Structure of it in Calves, &c. as fol-The very large splenic Vein having enlows. ter'd ter'd that Viscus and distributed its Branches every way throughout its Substance, appears to have small Foramina or Perforations in the Sides of its Branches, fufficiently confpicuous to the Eye as far as it can trace them, until the Vein is so minutely ramified as almost to vanish about the Extremities of the small Arteries, where the Nerve is also spent at the fame time; from hence it follows, that the fplenic Vein may be filled as well by these large lateral Foramina, as by the Extremities of those Vessels which are continued to the Arteries or Corpuscles like Glands; (§. 315.) and that therefore the ultimate Mouths of the small Veins may receive and return the Blood from the glandular Fabric, while these larger Orisices which open in the Cavities of the Veins, receive those Humours which may be evacuated into them from the adjacent Receptacles. while the Compages of the Spleen itself is strengthened by strong transverse Fibres.

Fabric of a part in twenty different Animals, it is probable she will not alter her Mechanism in the next Animal of the same Genus, even though the Fabric is somewhat more concealed from us; nor is there any Instance of a Viscus, which is of a different Fabric in Man from that in other Animals. I have myself diligently examined the Fabric of the Spleen in above twenty different Animals, and always found it as described by Malpighi: therefore, there does not seem to be any Necessity for searching after a different Structure in the human Spleen, even though it appears more friable than the same Viscus in Brutes.

§. 320.

§. 320. If Air be inflated through the folenic Artery 1 into the Substance of that Viscus which has had its Blood washed out, and the corresponding Vein afterwards strictly tied, that Air will be dispersed throughout the whole Substance of it, which is pervious; and if then the Artery be also tied, and the Spleen cut in two after it has been dried in the Air, there will not only appear many Arteries, Veins and Nerves, but also many distinct, empty and distended Cells, of various Forms and Capacities, composed of upright Membranes; which Cells have a manifest Communication with each other, and also with those larger Foramina, or lateral Perforations in the Cavities of the Veins.

This Experiment is indeed troublesome, but it always answers the Expectation. Take the Spleen of a found Calf, to which adapt a Siphon, and inject warm Water by the Artery, which will very speedily return by the Vein; continue the Injection 'till the Water returns as clear by the Vein, as it enter'd by the Artery. But even then it is not fufficiently cleanfed; but Water is to be feveral times injected, and gently pressed out by the Hands: and when at length the Spleen appears pale and bloodless, the Vein is then to be tied, and and Wind blowed in by the Artery. Thus the whole Spleen will fwell; and after tying the Artery in like manner, suspend it in the Air until it is dry. If then the external Membrane be peeled off, by holding it over the Vapours of hot.Water, the internal Fabric of this Viscus will appear, namely, a Congeries of Arteries, Veins, and Cells; which

which last are strengthen'd by Fibres of their own. and receive the Extremities of the Vessels on all Sides into their Cavities. Thus the Termination of one Class of Veins will not be conspicuous, where they are united with the Arteries; but the others will appear evident enough, continued from the large Cells, into which the Foramina of the splenic Vein open. Thus you see in one Preparation, a twofold Termination of the Veins is demonstrated; one continuous with the Arteries, as when the Water injected by the Artery flowed out by the Veins in the recent Spleen; the other opening into the Cells, which are eafily confpicuous in the dried Spleen. It must be confessed that this Preparation does not fucceed in the human Spleen. by reason of its great Tenderness, which will not allow of it to be thus treated. But yet in the Spleen of the gigantick Girl, (seven Foot high) which was injected by Ruysch, there appeared fomething like this Fabrick of the Calf's Spleen, namely, certain Corpuscles which might be esteemed Cells.

§. 321. The Sides of the Membranes which compose the foremention'd Cells are spread with exceeding small Arteries, but there are also small, white, and soft Corpuscles, of an oval Figure, disposed in numerous Clusters within the Membranes composing these Cells, and which seem to have all the sensible Appearances of Glands; but yet Ruysch takes them to be the ultimate and pulpy Extremities of the small Arteries, complicated together in Bunches after a particular Manner.

- Ruysch, who first admitted Glands in the Spleen, afterwards changed his Opinion, and would not allow there were any. The glandular Corpuscles in the Spleen seem to become pellucid, by washing them with warm Water; and they then disappear; but become visible again, after being injected or filled with some coloured Fluid.
- §. 322. In the mean time there are many large and distinct Nerves 1, continued into the Spleen only, and distributed throughout every Part of it, when at the same time there seems to be scarce any sensible Motion, nor any sharp Sensation performed in it; nor are any such Qualities observed to be necessary in it: from whence therefore it seems very probable, that even the Nerves convey their most subtle Humour 2 to this Viscus, into which it is distilled and mixed with the other venal Juices there found.
- Nerves so large and numerous, that Glisson takes the Spleen to be a Cistern for the Spirits; from the Reservoir of which some Addition is made to the nervous Fluid, and this he takes to be the Reason why there are so many Nerves entring the Spleen. But the same Physician, being a Man of Candor, even condemned his own Hypothesis after more mature Consideration, when he perceived that it was not agreeable to the Course of Nature to suppose two Origins of the Nerves, one from the Brain, and the other from the Spleen.

The Spleen is never in Pain to any great degree; and even in high Inflammations and large Tumors, in which a Schirrhus is formed, the Pain is felt only in its Membranes. There are many extraordinary Inflances of People who have been

opened

opened after Death, and their Spleen found enlarged to a very great degree, and yet they never made any great Complaints of feeling any Uneafiness in the left Hypochondrium. But these Nerves are here as little required for Nutrition, as for Sensation; we must therefore suppose the Nerves to conduce to fome Change in the Blood, which it may render more fluid in the Spleen by mixing itself therein. In short, the Spleen seems to be a fort of Lungs, in whose Cells the extravalated Blood is alternately shook and divided by the continual Action of the Diaphragm in Respiration. But as the Blood elaborated in the Lungs is conveyed into the Heart, fo the Blood of the Spleen is conveyed into the Liver; and therefore the Spleen is to the Liver, what the Lungs are to the whole Body.

§. 323. From hence therefore the principal Action of the Spleen seems to be, to receive, prepare, separate, and transmit the arterial Blood pure and diluted with Lymph, paffing through its fmall glandular Corpufcles 2 (§. 316.) by their proper Emissaries into each of the Cells (§. 320, 321.); and partly perhaps to transmit some of the same Blood into the splenic Veins 3. 2. To convey the Blood remaining after this Action to the small Veins. and from thence into the common splenic Vein. 3. For one Parcel of the small Arteries 4, namely, those which invest the Cells (§. 321.), possibly to pour in 5 the Blood, attenuated by the arterial Fabric, replenish'd with Lymph, into the ample Cavities of those Cells, as is observed to happen in the cellular Substance Substance of the Penis of the Male. 4. (As we believe) likewise to deposit, receive, and mix 6 a large Quantity of nervous Juice with the same Blood, to be constantly sent thither again. 5. To receive all these Humours thus prepared, confusedly mixed and stagnating for a Moment, so as to attenuate, intimately mix and press them together, almost in the fame manner 7 as the Blood in the Lungs; and this by the Force of the arterial Blood, the Impetus of the nervous Juice, the proper Contraction of its two membranous Coats and Vagina, the Contraction of its numerous Fibres, with the Agitation of the Diaphragm, and the Pressure received from the adjacent Muscles, Vessels, and Viscera of the Abdomen.

- It was mixed but a little before in the Heart with all the Humours of a more fluid Nature; nor does it part with any thing by the way, to form any kind of Secretion.
- which even Ruysch himself has admitted under a Name a little different, and less known, namely, that of Corpuscles. But their Office seems to be that of all other Glands, namely, the Secretion of some diluent Juice, which is poured into the Veins; as may appear from the patulent Mouths of the Glands, which correspond to the Veins.
- In this respect the Spleen differs from other Viscera, in that it secens nothing, and works by its whole Fabric, only to expedite or hasten the Course of the Blood from the Arteries into the Veins.

Veins. The same thing does also the Lungs, but without the Assistance of Glands.

4 This is the principal Means by which crude Chyle is digested into animal Fluids, namely, by forming it into Blood, compacting and agitating the same. The Blood which has suffered the Action of the Lungs and Arteries, passing through the Fibres of the Auricles and Threads of the Ventricles, will be therefore extremely sluid, and in the Spleen it will undergo a new Action related to that of the Arteries; and therefore it will be rendered the most apt for moving freely that can be possibly produced

by the Mechanism of the human Body.

The Structure of the Spleen appears (by §. 319, 320, 321.) to be the same with the Corpora cavernosa Penis; and therefore there is no Objection why the Motion of the Blood should not be alike in both; that is, for the Blood to be poured out of the Arteries into the Cells, and then to be again absorbed by the open Mouths of the Veins; for it is well known that in the Penis the Blood is poured out of the Arteries into the cavernous Bodies where it is retained by the Compression of the returning Veins preventing its Ressux, which Compression being removed, it is again received into the Veins by their Openings. The Intentions of Nature are in these Cases different, but the Mechanism appears to be the same.

It was faid before, (§. 322.) that the Spleen received more Nerves than any other Viscus, for which no other Use could be assigned than to pour in their Spirits to the Blood. But as there are no nervous Veins to be supposed, therefore the nervous Juice will be retained, mixt and elaborated

with the Blood.

be, 1. To distribute the arterial Blood attenuated by

the Heart, Lungs and Arteries, and to dispose it to pass through the infinite Ramifications of the smallest Arteries in its Composition. 2. To apply the Power of Respiration, or rather Effects of the like Nature, to the Blood in this Viscus; fince the Spleen is attached to the Diaphragm, and is every way obedient to the strong Pressures communicated from the circumjacent Parts. 3. To return the Blood thus prepared partly through the Veins, as in the other Viscera, and partly to pour it out of the Arteries into the Cells to agitate it by the Force of Respiration, to dilute it by a Quantity of arterial Lymph separated by the small Arteries which run upon the Cells and upon the Glands, proper to the Spleen itself; and lastly, to dilute it with the nervous Juice, and return it thus changed into the Vena Portarum. The great Use of it therefore to the human Body, is to prepare the Blood that it may be extremely fluid, and by mixing with the more flowly moving Blood of the Porta, render it fitter to circulate; in one word, to be a Diverticulum or Sinus to the Porta, as the Lungs are to the Heart; that is, to prepare the Blood in such a manner by its arterial Fabric, as to render it capable of passing freely through the smallest Vessels of the Liver.

§. 324. The Blood being thus attenuated, dissolved and mixed with the Lymph and Spirits, so as to be highly fubtilized 1 by these Causes, (§. 323.) will not easily coagulate, but remain intimately mixt, without being apt to concrete 2 or separate into dissimilar Parts; it will also remain of a purple 3 red, in the same manner as we observe it when extravasated from a large splenic Vein in this Part.

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Which Blood was but a little before expelled from the Heart, having parted with none of its more fluid Juices; but is diluted with arterial Lymph, replenished with nervous Juice, and as yet retains the Impression which it received from the Lungs and Respiration.

The Blood which has been discharged by cutting the carotid Arteries of an Ox after the manner of the Jews, immediately congeals; but the Blood which comes from the Spleen retains its Fluidity a long Time, nor does the Crassamentum easily depart from the Serum.

3 Which purple Colour the Ancients compared to a Blackness.

§. 325. This (§. 324.) therefore is the proper Action of the Spleen, which for that Reafon has no exerctory Duct, like other Viscera, by which they discharge some particular Humour that has been separated by their Fabric; but it returns all the Blood and Humours intimately mixt together.

retory Duct: for in the Lungs and Spleen, the Vein serves for an excretory Vessel to return the Blood after it has undergone the Essicacy of those Viscera. I make no doubt but that there is a Vein still to be discovered in this Viscus, which serves only for returning the Blood, which has been subservient to its Nutrition; and with that Vein there must be also a corresponding Artery. Of this we have a notable Instance in the Lungs, where we find a distinct Artery from the pulmonary, which serves for conveying Blood for the Nutrition of the Lungs; whereas the pulmonary Artery with its corresponding Vein, only transmits the Blood from

one Side of the Heart to the other, to receive the Impression of the Lungs for the good of the whole Machine: therefore besides this, there is also the Arteria Bronchialis, which with its corresponding Vein, serve for transmitting and returning the Blood proper to the Nutrition of the Substance of the Lungs themselves. The same Mechanism of Nature was also latterly discovered by Ruysch in the Intestines.

§. 326. From hence it manifestly appears, that the whole Benefit of the Action of this Viscus is not for its own Service; but as all its Humours are transmitted by the fingle 1 Vena Portarum to the Liver, it is therefore evident that the Use of the Spleen is to be subservient to the Liver 2, and that therefore its Use cannot be fully explained, until we have first examined the Office and Uses of the Liver.

Trom hence it is demonstrated, that the Spleen does not labour for the whole Body, but for the Liver only: for if it operated for the common Use of the whole, it would then transmit its Blood, not to the Vena Porta, but to the Cava; but there was never yet a Vein discover'd passing from the

Spleen to the Cava.

In the Liver the venal Blood performs the Office of that of the Arteries, as it enters that Vifcus through Veffels which are converging like Arteries: but the Obstacles or Resistances of these small Vessels could not be overcome by the Blood, unless it was assisted by some Machine communicating the same degree of Fluidity to it, as the Blood in other Parts receives from the Action of the

the Arteries. For this reason also the Blood returns into the Heart, which was not capable of overcoming the Resistance of the Arteries ramified from the Aorta: but to enable it to overcome those Resistances, the Lungs elaborate the venal Blood into the nature of arterial. What the Lungs perform in regard to the Aorta, that does the Spleen perform to the Blood in respect to the Vena Portarum: for in both Cases the venal Blood, namely, that of the pulmonary Vein, and of the splenic Vein, has all the Properties of the best arterial Blood.

§. 327. From this Doctrine of the Use and Fabric of the Spleen, many things may be understood, which are otherwise very obscure, and which may serve as a Confirmation; such, as for Example, are those which sollow:

What the Design is of the Situation 1, Bulk2, and pendulous Suspension 3 of the Spleen, and Action of the adjacent Parts thereon?

What is denoted by the Situation, Origin,

and Capacity of the splenic Artery 4?

Why and how long an Animal becomes more falacious s after the Spleen has been cut out? This is evident from the Situation of the spermatic Arteries.

Why the Spleen being cut out, is followed by a more frequent voiding of *Urine* 6? This is evident from the Vicinity of the renal Ar-

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Why the Animal becomes more voracious 7, who has the Spleen extirpated? This appears from the Situation of the coeliac Artery.

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What is the Cause of the rumbling Noise 8 or Belchings, with Vomiting and Sickness, which follow for some Days after the Splcen has been extirpated? This is also evident from the preceding, and from the Situation of the stomachic and splenic Nerves.

Whence arises the Tumor 9 of the right Hypochondrium, and Enlargement of the Liver,

after the Spleen has been removed?

Why fplenetic 10 and hypochondriacal Patients have all the forementioned Symptoms, with a Paleness?

From what Cause those Patients are more prone to Laughter 11?

- With respect to the Vessels of the Spleen, it was necessary for them to arise before those of the Liver, since this Part prepares its Blood for the Liver. But with respect to the Situation of the Viscus itself, its Nature and Office required it to be placed near the Heart, contiguous to the Diaphragm; and so attached to the Stomach, that when that is distended with Aliment, the Spleen will be consequently compressed alternately, as it also will be by the Action of the Diaphragm and abdominal Muscles. For in this Part of the Abdomen, the Tendons and Insertions of the oblique and transverse Muscles meet together, and, as it were, terminate their Action in a Center.
- Its Bulk is confiderable enough, if you obferve that it is not made up with Fat or Muscles, but of Arteries, Veins, and Nerves only, without any excretory Ducts.
- This in order that it might be pressed equally on all Sides, lest if it should have been fixed to the Back,

Back, it might in that Part have been destitute of its Pressure.

These Arteries are very near to the Heart, and the largest of those belonging to the abdominal Viscera, quite free through their whole Course, and continually subjected to the Essicacy of Respiration, by which means they convey their Blood as plentifully and swiftly as possible to the correspond-

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Malpighi and Bohn cut out the Spleen in Dogs, having first tied the Vessels to prevent a dangerous Hæmorrhage; and after healing up the Wound of the Abdomen by Suture, they observed the following Events: 1. That those Dogs were extremely lecherous; and this because the Blood of the Aorta being denied a Passage into the considerable splenic Artery, therefore slowed more plentifully into the Spermatics; whence a greater Quantity of Semen being secreted, therefore the Appetite of discharging that Humour was also increased. But this Salacity is but of a short Duration; for the Animal cannot long survive in a healthy State, under so great an Injury offered to the Liver.

They in the second place observed, that the Animal voided his Urine more frequently, plentifully, and watery; and this for the same Reason which we last mention'd, namely, a more copious. Determination of the Blood into the emulgent Ar-

teries, as well as into the Spermatics.

Thirdly, The Animal became more voracious, as well from the increased Secretion of the gastrie Liquor, from whence Hunger in some measure arises (per §. 88.) as from the greater Efficacy or Action of the muscular Coat of the Stomach. This likewise arises from the same Cause, namely, the Blood which went into the Coeliac being excluded

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from

from the splenic Branch, therefore enters in a larger Quantity through the Mouths of the sour arterial Branches, which come from the Coeliac, and are spent upon the Stomach. But neither is this Voracity of any long Duration, since the whole Preparation of the Chyle is thus injur'd, by re-

moving this important Viscus.

Such Tumults were observed in the Abdomen, that the Animal has been observed to be frighten'd out of his Sleep with the Noise, and to prick up his Ears, looking round, to learn from whence so great a Disturbance proceeded. These flatulent Disturbances seem to arise from the Perversion of the Blood's Course through the Intestines, by which their Contents are hurried on by an Increase of the peristaltic Motion, and the confined Air being accumulated, is exploded or discharged at particular Times; the Cause of all which Disturbance is the Blood's slowing into the mesenteric Arteries in an increased Quantity.

9 It is obvious to every body, that when the Spleen has been cut out, the Liver will be more turgid; which would therefore feem to infer, that the Blood of the Spleen did not pass to the Liver, But we only learn from this Experiment, (1.) That the hepatic Branch of the coeliac Artery receives more Blood from the Destruction of the splenic Artery. (2.) That the Efficacy of the Spleen in diluting and attenuating the Blood being destroyed, therefore the Blood flows more difficultly through the Liver, stagnates and obstructs the Vessels, and by that means distends this Viscus to a morbid Bulk. Therefore three or four Months after the Spleen has been cut out, the Liver will be fwell'd, and a Tumor formed in the right Hypochondrium, which must be troublefome to the Animal.

10 By this Name the Ancients call those People, who wasting in their whole Habit besides, suffer an Enlargement of the Spleen; though from the Seat of the Diforder they have been rather termed by the Moderns hypochondriacal People. In fuch Persons there is a leaden Colour of the Face, accompanied with all the Symptoms which were before mentioned to follow in an Extirpation of the Spleen in Dogs. They are falacious, and discharge their Semen even to a Weakness in their Sleep, that is, in the Beginning of the Disease; for when it is confirmed, they are more cold in this respect. They discharge much Urine, which is watery; they are voracious, abound with Flatulencies, which they discharge with a considerable murmuring; and laftly, as we faid before, the Liver itself swells; a Tumor of which is always obferved in Men who are extremely fplenetic.

" It has been observed, that Actors, who get their Living by procuring the Laughter of the Publick, being full of Gesture and Facetiousness. are also falacious, and generally hypochondriacal, being scarce able to contain themselves in Spirits. until they return again to their ridiculous Entertainment of the Publick. It does not feem an easy matter to explain Laughter. What it is in the Nerves we know not, but perhaps another Age may know more of it; but this we can tell. that the Mind puts the Parts in a Posture of laughing at the fudden Appearance of any thing which is abfurd. As to the Cause of it in the Body, it is placed in some Disposition of the Diaphragm, which being inflamed causes involuntary Laughters. Therefore the Laughter to which hypochondriacal People are inclined, may be accounted for from the Regurgitation of the Blood into the adjacent phrenic Arteries, as being ob**structed** 

structed in the Branches of the splenic Artery; while at the fame time the Spirits flow back in the fame manner from the splenic Nerves into the adjacent Nerves of the Diaphragm.

§. 328. We may also from hence be able to judge, whether the Spleen is formed only as an Equipoise 1 to the Weight of the other Vifcera, and to stop up a Cavity? Whether it is an useles Mass 2 of Matter? Whether it is an Error 3 committed by Nature in a Lethargy? Whether it is to serve as a Sink 4 or Closestool for clearing the Blood of its atrabiliary Fæces? Whether it is the Seat of a Ferment 5, or of a Fire-place, or the vital Heat, by whose Rays the digestive Power of the Stomach is excited? Whether or no it is the Seat of Luxury and Lechery, as well in those who are awake, as in those who are ludicrous in their Dreams? Whether or no this Part being disordered, disturbs the procreative 6 Faculty, and renders the Person sterile? Whether this is the Seat of Indolence and Rest, or Sleep 7? Or whether the Ancients more rightly make it to be the Throne of Laughter, Joy 8, and Mirth? In short, all these Conjectures must be dissipated by the Light which Malpighi has given us by his Observations on the Fabric of this Organ. Nor is the Opinion of Gliffon more probable than the former, who once imagined the Spleen to be a second Reservoir to the nervous Juice 9, to be taken up and fent from thence by its many Nerves. Nor has that Opinion any more Foundation, which supposes that all the Blood

' Several of the Ancients have taught, that the Spleen was formed to act as a Weight in pulling the Diaphragm downward on the left Side, as the Liver does on the right. But in this they injure the Honour of the divine Architect, supposing him to have no other Design in the forming of this Part than to fill up a Cavity. For Symmetry does not appear to have been studied by the Architect in the internal Parts, which are never exposed to Sight; and therefore Nature has very well spared herself the Pains of an exact Symmetry in the Heart, Stomach, Pancreas, Mesentery, Spleen, &c. where it would have been quite useless. In short, the Duplicity of many Organs is not made for the fake of Symmetry, but that the Animal might enjoy the Benefit of one Part. which is of the last Importance, if he should by Accident be deprived of the other.

It is a little wonderful, that many wife Men among the Ancients should be persuaded that God and Nature make nothing in vain, and yet that some of them should stupidly suppose the Spleen to be a mere Weight: for certain it is, that every, even the least Part of the human Body contributes something to the common Good of the whole.

Drunken Prometheus feigned the Spleen to be an Error of Nature; an Opinion certainly as

foolish as impious.

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have built upon this System, that all the Chyle necessary for Life and Nutrition, was taken up by the mesenteric Veins and conveyed to the Liver; but that this Chyle was as yet a crude Liquor and very foreign to our Nature: but yet that all the

Parts which were nutritious in the Chyle, were conveyed to that very bloody Viscus the Liver, and there formed into Blood. But the Chyle being stock'd with a large Quantity of Fæces, it was necessary for them to be first separated, before the rest could be formed into radical Moisture: Hence therefore that there was a Separation made of two Sorts of Excrement in the Liver, the one vellow Bile, which flows into the Duodenum and tinges the Fæces; the other a malignant or black Bile, the worst of all Excrements, which is conveyed to the Spleen there deposited and collected, that it might not prove the Cause of great Disorders in the human Body. But all this we have in part refuted before; and it is in part repugnant to the known circulating Course of the Blood; by which we are taught, that nothing is conveyed from the Liver to the Spleen by the fplenic Vein, but on the contrary, that all the Blood of the Spleen flows to the Liver, as is evident from the Structure of the Veffels, as well as from Experiments made on living Animals. Add to this, that the Blood of the Spleen is so far from being feculent, that it exceeds all the rest in Fluidity and florid Colour.

Basile Valentine, Isaac Hollandus, Paracelsus, Helmont, and the rest of the chemical Sect, oppofed the Schools with their new System, supposing that there was no Change wrought in the internal Parts of the human Body without Fermentation. That in the Stomach the crude Aliment was converted into Chyle by a Ferment, which the Stomach stood in need of. Moreover, that these Ferments were all acid; but yet that this Ferment could not be generated in the Stomach itself, from whence the Source of it would be foon washed away or destroyed; and therefore that there could be no Viscus which was able to supply this Fer-

ment to the Stomach besides the Spleen. The Spleen then they made the fecretory Organ of a vital Acrimony or Ferment, which was conveyed into the Stomach by the Vafa Brevia, and there proved the principal Cause of Digestion. But even Helmont himself confesses, that a true Acid is not natural nor indigenous to any Part of the human Body, but is rather an Enemy; and therefore such cannot be feated in the Spleen; befides, nothing can flow from the Spleen to the Stomach by the Laws of the Circulation, but on the contrary, the Blood is carried from the Stomach by the Vafa Brevia into the splenic Vein. But if any one should ask why there are so many Communications betwixt the Veins of the Stomach and those of the Spleen, we answer, that the Stomach is a Viscus so alterable, that it may be much diftended by the Food. fo as in a great measure to intercept the Circulation, by compressing its Arteries, and produce the worst Consequences: To prevent which, Nature has placed Veins all round the Stomach, into which the Arteries may very speedily evacuate themselves, by fending their Blood into the large unrefifting splenic Vein.

6 This was also an Hypothesis of Helmont, which has been long ago refuted by Malpighi, from whose Experiments it appears, that Animals who have lost their Spleen are more prolific and inclined to

Venery.

Also this Opinion seems to have been started by Helmont for no other Reason, than because those People sleep well who have their Spleen in a healthy Condition, while those who are splenetic are restless. But this Watchfulness arises no more from the Spleen than from all the other Viscera when obstructed: for the obstructed Spleen does not destroy Sleep from any peculiar Disposition of itself,

but only because the Blood obstructed below is sent up in a greater Quantity to the Brain. For the same Reason likewise, if the Feet are cold and the Head hot, as frequently happens in studious People, they can never sall into a Sleep till their Feet are first become warm.

8 It is an old Saying, that the Spleen causes Laughter. But whether this arose from an Observation that splenetic People are generally cross, is a Question; but this is certain, that Joy depends much upon a free Circulation of the Blood through all the Viscera and Vessels of the Body, which being obstructed, produce Anxieties, and an uneasy Sense to the Mind. Therefore it may be fairly concluded, 1. That the Spleen being found and free from Obstructions, conduces something to the Alacrity of Animals; fince it attenuates and renders the Blood fluid, that it may easily pervade the Parts which are in the greatest Danger of Obstruction: and, 2. For the same Reason Sadness will follow if the Spleen is obstructed, fince itself will be invaded with an obtuse Pain or Anguish, and will not attenuate the Blood as usual, and as is necessary to perfect Health.

9 This Gentleman supposed the Spirits to be drained from the Blood into the Cells of the Spleen, and that from thence they were absorbed by the splenic Nerves. But this Hypothesis he afterwards

abrogated as we observed before.

This was the Hypothesis of Sylvius, namely, that the Spleen elaborated the Blood, rendered it very subtle, sluid, sull of Spirits, and in a manner more than perfect, that it might correct the rest of the Blood with which it mixed in the Body. He was right in thinking that the Blood of the Spleen was best conditioned, and in a manner more perfect or subtilized than that of other Parts of the Body;

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but he was out in his Doctrine, that the Blood of the Spleen was to correct the whole Mass; since all the Blood of the Spleen is conveyed only to the Liver; whence it follows, that the Spleen labours only for the Liver, to which it is a kind of Lungs, and that it does not immediately work for the general System of the whole Body.

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The Action of the OMENTUM,

S. 329. BUT while the Blood (§. 324.) thus prepared, flows from every Part of the Spleen by several Veins into the great splenic 1 Branch, in order to pass on through the Vena Portæ to the Liver, it there meets in its Course and mixes with the venal Blood returning from the Omentum by its proper Veins 2; and this Mechanism we see constantly observed by Nature as a Law.

This large Vein runs parallel to the Horizon, being fingle all the Way of its Course, and inserted into the large Vein of the Mesentery. At the Place of this Insertion there is a surprizing Conflux of different Veins, as they are elegantly expressed by Tables of Vesalius and Eustachius.

<sup>2</sup> Which are called Adiposa or Epiploica, one in each Side, which return only the Blood which has been elaborated in the Omentum, the Blood of which Viscus is conveyed into the splenic Vein, and from thence into the Vena Portæ. Therefore the Omentum seems to labour wholly for the Liver, to which it transmits all its Blood.

5. 330. If

§. 330. If we confider the Connection 1, Situation, Structure, and Infertion of the Omentum with its great Tenuity 2, which is compared to a Web of the finest Silk, by Malpighi; and if we also compare its Structure with the Discoveries which have been made by the Industry of Anatomists in several Kinds of brute Animals, we shall find, that from the Arteries of the Omentum, which are distributed into very minute reticular Plexus's upon the Surfaces of the Cells 3 or Bags which contain the Fat, upon which Cells they terminate in small Veins disposed in the like Order: I say, we shall find that a thin and subtle Oil is separated by lateral Ducts from those Arteries, and conveyed into the adipofe Cells, where it is collected, retained, and highly attenuated by the continual Warmth, Motion, and Attrition, so as to become more volatile, acrimonious, and like unto the Bile; fo that at length this collected and thus prepared Oil is expelled from the communicating Cells of the Omentum through certain open Ducts into the Veins, which convey it to the Liver 4, where it also mixes with the Blood that comes thither from the Spleen.

<sup>&</sup>lt;sup>2</sup> The Omentum is a thin Membrane, which descends from the lower Edge or Bottom of the Stomach down to the Navel, where it again afcends backward up to the Colon, into which it is inserted; so that its Plates form a Bag, in which there is an empty Cavity called the Duplicature of the Omentum. This membranous Bag is not on-

ly spread over the Intestines, but it also infinuates itself betwixt the Convolutions of the Intestines, and fometimes it even adheres to the Melentery. Now it is within the Cavity of those two Membranes that all the Vessels of the Omentum are feated. Vefalius has given us a Figure of this Part, which Eustachius perceiving to be true, has not opposed it with any other of his own. But the Cavity betwixt the two Plates or Membranes has been discover'd by Winslow, after making a fmall Wound through one of them, and inflating with a Blow-pipe. Besides these principal Connections of the Omentum, it also adheres to the Pancreas, Duodenum, Spleen, the Bottom of the hepatic Vessels, and to the Mesentery. It is spread in fuch a manner under the Peritonæum, that no Part of that Membrane in the Abdomen can be applied naked to the Stomach or Intestines; fo that it is no easy matter for them to be injured in violent Motions of the Abdomen. For there is a continual Attrition betwixt the Peritonaum and the Viscera contained in the Cavity of the Abdomen, when the Viscera are either pressed downward against the Peritonæum by the Descent of the Diaphragm in Inspiration, or when the Peritonæum presses itself against the Intestines by the Contraction of the abdominal Muscles, so as to return the Viscera upward and backward. The Omentum is therefore interposed, as being soft and spungy, to infringe and break off the Violence of the Pressure betwixt these Parts. It does not descend usually much lower than the Navel, because the Force of Respiration is but weak in the lower Part of the Abdomen.

<sup>&</sup>lt;sup>2</sup> If the Fat and Blood-veffels are removed from this Membrane, its Tenuity will appear almost incredible.

credible, infomuch that Ruysch pronounces that there is not a thinner Membrane to be found.

3 The Microscope demonstrates, that the smallest fanguiferous Arteries are continued into little Cells full of fubtle Oil; of which Cells almost the whole Substance of the Omentum is composed: for if the Fat is exhaufted or melted out from them, which fometimes happens in brute Animals, there then only remains a thin shriveled-up Membrane.

It was equally necessary for the Fat to have Ducts to carry it as well from, as into the Cells. For as it is perpetually brought by the arterial Blood, and yet the Omentum does not grow to an immense Bulk; it therefore follows, that as much of the Oil must pass off somewhere by the Veins, as there is brought of it by the Arteries. But for this purpose we find no other reductory Vessels befides the Veins; and therefore the Oil of the Omentum must be conveyed by the Veins to the Liver, fince that is the Part into which these Veins difcharge their Blood. It is therefore highly probable, that Part of this Oil goes to the Formation of the Bile, after it has been elaborated, attenuated, and in some degree turned rancid and bitter in the Omentum, which fuffers the Efficacy of Respiration, and of the peristaltic Motion of the Intestines. Malpighi has even demonstrated to the Eye, that the Fat is conveyed by particular Ducts to the Liver in brute Animals, as in Frogs and Fish. But notwithstanding this, I also allow that there is an Evaporation of the more subtle Part of the Oil through this Membrane, which like an oily Vapour infinuates betwixt the Convolutions of the Intestines, and betwixt them and the Peritonæum, to lubricate and facilitate their Motion, and prevent them from growing either to each other or to the Peritonaum.

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§. 331. It also appears probable, that an Exhalation of Vapours extremely fubtle, and apt to be imbibed again, infinuates itself into the whole Omentum, in the Form of a fine Vapour, after it has been exhaled from the Mouths of the innumerable small Vessels, which are diffributed through the Omentum, whose Membranes are extremely thin; which Vapours infinuating themselves into the Omentum, are continually supplied by the subtle Dew distilled into the warm Cavity of the Abdomen from the very minute Orifices of the exhaling Veffels 1; and by these oily Vapours, the Surfaces of all the Parts contained within the Peritonæum are continually moisten'd, lubricated, and mollified. But we must necessarily suppose this Vapour to be extremely fubtle and volatile, if we confider its Nature, Origin, continual Waste and Supplies, with a Smell which it affords upon opening the Abdomen of an Animal that is warm.

Ruysch has found, that by carefully taking out the Omentum from young Animals and drying it, it appears perforated on all Sides with very small Pores. And besides this, the Abdomen in all Animals is continually replenished with moist Vapours, which affect the Nose with a peculiar rank Smell differing in each kind of Animal. The Vapour we now speak of, exhales continually; and yet we do not observe it accumulated into Water, fince in the Bodies of People who have died in Health, all the Viscera appear lubricated with a thin Oil without any Water extravasated. fore

fore as it continually exhales, it must also be continually absorbed, and there must be venal Ducts for the Absorption corresponding to those arterial Ducts, from whence the Vapour is exhaled; and by this Artifice only could Nature prevent the Parts from becoming dry, without fuffering any Quantity of Water to be accumulated. A Defect of the Secretion of these Vapours will render the Parts dry and rough; and a Defect in their Abforption will cause a Dropsy or Ascites. But there does not feem to be any Organ better adapted for this Absorption than the thin Plates or Membranes of the Omentum, to draw in the abdominal Vapours by the very patulent Mouths of the Veins, in the same manner as we find the Oil or Fat exhaling from the Vessels of the Omentum, (§. 95. 330.) Hence it is that we have no Instance of a dropfical Body with a found Omentum. Hence then this femiputrid highly attenuated Vapour, which is one of the most volatile of the animal Humours, feems to be absorbed by the smallest Veins of the Omentum, which return it into the larger epiploic Veins, from whence it passes into the Vena Porta. This Doctrine is also confirmed. as well by the Return of the Water in dropfical Patients, as by an Experiment designedly made by Nucke. He made a small Incision in the Scrotum of a live Dog, so as to form a Paffage into the 'Cavity of the Process of the Peritonæum, which in that Animal affords a free Entrance into the Abdomen: By this Wound he injected feveral Ounces of warm Water, fewing up the Abdomen afterwards, fo that none of it could escape, and tying up the Dog in his Chamber, upon the Floor of which there was not fo much as a drop of the Water spilt. The Dog discharged a large Quantity of Urine, and upon opening his Abdomen fome

fome Days afterwards, there was not any extravafated Water to be found; which is a certain Sign of the speedy Absorption which is here made.

§. 332. But as the Omentum is not obferved to have any other excretory Vessels in Man, except two Veins which are called the right and left Epiploic; it is therefore probable, that the venal Blood of the Omentum, replenished with the Lymph (§. 331.) and the Oil (§. 330.), are all intimately mixed and conveyed together to the Liver 1.

Thus therefore the Use of the Omentum in the human Body appears gradually more and more manifest, namely, for its Fat or Oil, which is become fubtle, rancid, and bitter by the perpetual Warmth and Attrition, to be conveyed into the Liver for forming the Matter of the Bile, to be there separated from the venal Blood. This Doctrine is confirmed by the Observation of Malpighi, who saw adipose Ducts in Frogs, which being pressed apparently discharged Drops of Oil into the Vena Portæ. Hence it is that the Livers of Fish are in a manner buried in Fat, and the Liver of a Cod-fish discharges a mere Oil by Pressure, and even almost entirely melts into Oil. For as these Fish are very voracious, and live in a cold Element, they therefore require a very large Quantity of an exceeding bitter Bile. Nor ought it to be objected, that it does not feem probable, fo smooth a Fluid as Oil should be elaborated into a Humour so extremely bitter as the Bile: for all Oil itself becomes yellow, acrid, and in time very bitter, barely by Heat and Attrition, as we are taught by chemical Experiments. Even the Fat D 3

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§. 333. From hence we may understand, why the Omentum grows to fuch an immense Bulk 1 in Animals that live at Rest? Why, on the contrary, this Part is quite thin and membranous, and its Veffels rather filled with a Humour which appears like Serum 2 than Oil in Animals addicted to too much Labour? And why also its Vessels are almost continually filled with a thin Serum in emaciated and dropfical Subjects? And laftly, it appears that there is a greater Derivation of the collected Oil of this Part into the fplenic Vein, in proportion as the Blood's Motion 3 is increased. It also appears, why the Omentum is fastened near all the Viscera which are destitute of Fat 4.

A certain rich Citizen, who took Pleasure chiefly in the Gratification of his Appetite, having his Food and Drinks prepared in the most exquisite Manner, grew fo fat that he was obliged to fupport his Belly by a Safh hung over his Shoulders; nor was he capable of fitting at Table fo as to reach with his Hands, unless where there was a round

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Cells.

Part of the Table cut out to receive his Belly. After the Death of this Person, the Omentum being cut out, weighed thirty Pounds. Thus also in Hogs, Calves, &c. before fattening, the Omentum is as thin as Paper; but after a few Months it becomes fo fat, as totally to obscure the Bloodveffels. For in the Omentum the Blood's Circulation is very flow, if it is not forwarded continually by the Respiration: But the Motion of the Arteries is always stronger than the Resistance of the adipose Cells; and therefore when the best or most oily Part of the Chyle is continually conveyed through the Arteries, while nothing is returned but the mere Blood by the Veins; it follows, that all the Fat or oily Parts of the Chyle must be poured into the loofe Cells, into which the Arteries open.

In a Post-Horse the Omentum is thinner than the finest Post-paper, which we generally use for Letters, upon the Account of its Lightness: for by the continual and strong Attrition which is made upon this Part, the Oil is so attenuated as to partly exhale in the former Vapours, and partly to be absorbed or pressed into the Veins, which return it into the Blood. Even by the violent Exercise of a Horse which has been fatten'd in the Stable, Ruysch has observed the Cells of the Omentum to be burst open, by the hard running of the Animal; by which means Death has followed in a little time, and many Pounds of true Oil were found extravasated in the Cavity of the Abdomen.

3 Thus it is in the Omentum of old people, and those who are emaciated or dropsical: for in these the Place of the consumed or exhausted Oil is supplied by the stagnating watery Vapours which are absorbed. For the first Sign of a Dropsy is a certain gelatinous Humour collected in the adipose

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Cells, as has been demonstrated in the arachnoide Membrane of the Brain itself in a diseased Body: But so soon as the Water has enter'd the Cells of the Omentum, it then putrifies in a very short time.

\* The Attrition is at that time the greatest, by which the Blood inclines to the most intense lixivial Acrimony, the Bile becomes also more acrid, and all the Humours require more of the obtunding Oil to sheath the actuated Salts. Nothing is therefore more suitable than oily Emulsions, whenever the Blood degenerates into an acrimonious or corroding State by acute Diseases, which actuate its Salts, and render its oily Parts rancid. And this is the Reason, as Malpighi well observes, why Nature has more bountifully supplied those Parts with Fat or Oil, where there is the greatest Attrition, or where the Humours are more acrimonious.

Such as the Peritonæum, Surface of the Intestines, Stomach, and the convex Part of the Liver and Spleen: for all these Viscera are lubricated, and prevented from rubbing so as to injure each other by their Contact. But it is not joined to the Mesentery, because that is naturally replenished with its own Oil.

§. 334. But with this Blood (§. 324.) is also mixed that which returns from the Membranes of the Stomach by the Vafa brevia, the Gastrica major and the Gastro-epiploica, both right and lest, and the Pylorica; all which Blood being deprived of that Lymph which it distils into the Cavity of the Stomach, does therefore mix in several Places with the Blood returning from the Omentum (§. 332.);

and perhaps it carries with it a good deal of the most subtle Humours 2, which have been derived from the thinner Juices of the Aliments absorbed by the Veins of the Stomach. Hence the Reason is also evident, why the venal Blood of the Stomach discharges itself by fuch a great Number of Vessels, distributed according to its Length; to wit, that the Discharge of this Blood might not be impeded by the Diftention of the Stomach, when filled with Aliments; whereas its Course might have been eafily stopped, if it had been difcharged by one Vein only.

The Stomach is fo formed that it may be capable of a great Alteration in the Dilatation or Contraction of its Capacity; and therefore there would be Danger of compressing its Vessels in sudden Diftentions, so as to intercept the Blood's Circulation as often as it is filled with Aliments; nor was it possible for the Vessels to be commodiously inferted near the Orifices of the Stomach, fince when it is filled they are brought near to each other, and therefore the Vessels would consequently have been there compressed (§. 85.) But to prevent this, Nature has provided (1.) that the Stomach should be furnished, not with a single arterial or venal Trunk, but with feveral smaller ones, that if one Vessel should be compressed, the rest might remain pervious. (2.) She has fo conjoined these Vessels with each other by Anastomoses, that if the Blood is obstructed by the Compression of one Veffel, it can continue its Course on through the other Veffels with which it communicates. One Class of these Blood-vessels of the Stomach are fix or eight Veins called Brevia, conveying the Blood from

from the bottom of the Stomach to the splenic Vein, for about the Length of an Inch; for this was the shortest Course for the Blood to return into

any confiderable Trunk.

We faid before (§. 87.) that it was probable the most subtle Particles of the Saliva, Aliments, and spirituous Liquors, with the animal Spirits transfused into the Stomach, were continually abforbing by the bibulous Pores which open in the Surface of that Organ; but whatever is absorbed by these Orifices passes into the Veins of the Stomach, which consequently send their Contents to the Vena Portæ.

§. 335. But besides these, there are also other small Branches returning the venal Blood from the Pancreas, which are also followed by the internal *hæmorrhoidal*<sup>1</sup> Veins: which also send their Blood to the Liver, perhaps more abundantly replenished with *acrid Particles*<sup>2</sup>.

All the Intestines transmit their Blood to the Vena Portæ, except only the Rectum, which but in part sends its Blood to the Liver by the internal Hæmorrhoidals, and partly to the Cava by the ex-

ternal Hæmorrhoidal Veins.

For fince the Fæces of the Intestines are putrified chiefly in the Colon and Rectum, their fætid and rank Vapours will be continually taken up by the Veins which are there seated, being partly absorbed, and partly penetrating by their own subtle Nature; and this volatile alcaline Vapour seems to be a necessary Ingredient towards the Formation of the Bile.

§. 336. Finally, all the Blood which was conveyed to the Mesentery and Intestines by the

the upper and lower mesenteric Arteries, having there performed its Office, returns through the mesenteric 1 Veins, and at length mixes with all these returning Humours before they enter the Liver. But this last Blood from the Intestines and Mesentery, has been also in a great measure deprived of its Lymph, (§. 91.) some of which forms the intestinal Juice, and being partly perhaps replenished with the more fubtle Parts of the Chyle, (§. 106.) it furnishes proper Matter for the Formation of the Bile. But there is also a large Portion of this arterial Blood fent to the Mesentery and Intestines. which is carried back by other Veins of a distinct Order, dispersed through the Membranes of the Intestines and Mesentery; and these Veins do not open into the large mesenteric Vein, and therefore they do not carry their Blood to the Vena Portæ, but to the Vena But then the Origin, Course, Ramification and Termination of these Veins is very different from the miseraic Veins which pass to the Vena Portæ: for every Viscus has Veins returning the Humours which are fuperfluous after the Nutrition is performed, and other Veins which return that Blood which is brought to each Viscus for its publick Action or Use.

All Anatomists generally agree, that there is no other Way for the Blood to return from the Intestines. But in the Year 1720, I received Letters from Ruysch, in which he candidly communicates, that he had filled the Vena Cava at a small Distance

Distance from the Liver with ceraceous Injection. and after tying it above and below, he found a great Number of its venal Branches appearing throughout the Mesentery and whole Tract of the Intestines. But these Veins appear to be distinct from those Branches which belong to the Porta, as was demonstrated by injecting the Vena Cava and Vena Porta separately in the same Subject. And he observes, that the Nature and Distribution of these two venal Systems and their Branches, are furprizingly different. Thus therefore there feems to be a twofold Circulation of the Blood in the Mesentery and Intestines, one commonly known, in which the Blood brought by the cæliac and mesenteric Arteries, (deprived of its mucous and falival Juices which distill into the Cavity of the Intestines, and inftead of that replenished with the more subtle Parts of the Aliments, Bile, and intestinal Juices,) returns back by the Vena Porta to the Liver. For that there is an Absorption of the Bile (§. 106.) we are fully persuaded, 1. Because the Chyle which mixes in the Intestines with a very bitter yellow Bile from the Gall-bladder, is nevertheless white and sweet in the lacteal Vessels, and therefore it must necessarily have deposited all or the greatest Part of the Bile which it had before received. 2. From the peculiar Nature or Condition of the Blood returning by the mesenteric Veins, which appears of a dark yellow, very fluid and different from any Blood found in other Parts of the Body; which Difference feems to arise from the Bile, fince a Bitterness has been several times tast. ed in it by various Anatomists. 3. From the Effects of the acidulæ purging Waters, which fooner remove Obstructions of the Liver than of any of the other Viscera. But there is besides this another Circulation of the Blood in the Mesentery, by the Veins

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Veins which return the redundant Blood after the Office of Nutrition into the Cava, as Ruysch lately discovered; and I am in no small Hopes but that there may be also corresponding Arteries discovered by injecting the Aorta, so as to fill it very exactly with ceraceous Matter, after tying the mesenteric Arteries.

§. 337. The Blood therefore which flows immediately through the Vena Portæ into the Liver, is very fluid 1, highly attenuated, diluted with Lymph and replenished with the old returning Humours, especially the Spirits and Bile; and thus these several Humours, very different from each other, and returning from different Quarters, are intimately mixed in the large Sinus or venal Trunk where they concur; and this Mixture is rendered more perfect, partly by the Force of Respiration which acts powerfully upon these Parts, (§. 86.) and partly by the Impulse of the Blood itself, by which means it is rendered fit for Secretion, and capable of passing on afterwards into the Veins.

The principal Design of Nature in placing the Omentum and Spleen under the Pressure of the Diaphragm, seems to have been to forward the venal Blood in the Branches which tend to the Porta; for otherwise it would pass on with too weak a Motion which it received only from the Arteries destitute of the Force of the Heart: whence this sluggish Blood destined to pass through a fort of converging Arteries, is by this Motion continually excited to circulate and overcome the Impediments which might otherwise cause it to stagnate. From

all these Phænomena we learn that the Blood of the Vena Portæ is very fluid, scarce congealable, and not very red; whence it is well adapted to be distributed through all the smallest Vessels of the Liver without Danger of caufing Obstructions; all which is further promoted by the alternate Preffure communicated in Respiration, by which the Lymph and thinner Humours from the Intestines and Spleen, are also blended with the other Parts of the Blood.

## Of the Action of the LIVER.

HE Vena Porta therefore being composed of fo many Veins, converging together into one Trunk, rifing upwards, it enters the Liver 1 about the middle of its concave Surface, betwixt the Tubercles or Protuberances which are called (mulas) Gates 2, and foon after acquiring a firm and frong fibrous Coat or Capfule 3 like the Tunics of the Arteries, it forms a large Sinus 4 for about the Space of half an Inch, in which the several Humours being impelled, collected, mixed 5, and retarded in their Course, are further divided by the Motion and Action of Refpiration 6, fo as to be intimately mixed, and afterwards more equably distributed throughout the Liver.

The Liver is a Part wanting in no Animals, as far as we can discover, and is generally larger in proportion as the other Viscera are less, as we

fee in Fish and Infects. In Fish there is no Thorax, but a very large Abdomen, which is mostly filled with the Liver, Pancreas, and a few Intestines, as I have observed in the old-Wife-Fish; and in the Canis Carcarius, which weighed three thousand Pounds, there was almost one fixth Part of it Liver, from whence it is evident that this Viscus is of the last Necessity to Life.

This Passage has derived the Name of Gates from the Similitude of a Way passing between two Hills, which the Greeks called Pylas, as Thermophelas, &c. and it is from that Valley through which the large Vein of the Liver passes, that it has derived the Name (are provided in Vena Portarum, from whence the common Name Vena Porta is im-

properly derived.

Such a Strength was altogether necessary in the Veins of the Liver; for as the Blood is there to pass from a large Trunk into narrow Branches, and this with little or no Assistance from the Contraction of the Heart, through a Vessel which does not propel its Contents by the Elasticity of its Coats; therefore the Blood would never have been able to overcome the Resistances of the smallest Vessels which it passes, if the common Sinus was not contracted by a muscular Membrane, which forwards the Blood into the Liver.

The Vena Porta is expanded into a large Sinus, in the same manner as the Vena Cava is diluted into the right Sinus of the Heart: Nor is this the only Similitude, since the Sinus of the Vena Porta is as much a Heart to the Liver, as the Heart, properly so called, is to the whole Body: for all the venal Blood is here received in its Passage to the Liver, and then the thin Vein of the Porta is invested with a strong sleshy Integument, which was first descried in the Liver by Glisson,

who has denominated it a Capfule: whence it has been called the Capfula Glissonii. Nor shall we be liable to any Exception, if we call this Cavity of the Liver by the Name of the venous Sinus.

of the Porta, to wit, the splenic, epiploic, gastric and mesenteric, went each of them distinctly or separately to the Liver; then only one Portion of this Viscus would have received the oily Part of the Blood, another Portion would have received the watery or thin Blood of the Spleen, while the acrid intestinal Blood would have been carried to still a different Part of the Liver; and therefore the Bile, which requires a Mixture of all those Humours, could not have been formed.

6 The Force of which is not inconfiderable; for the Liver is suspended to the Diaphragm by a large and strong Ligament, and therefore the Liver follows the Agitation of the Diaphragm every

time it moves in Respiration.

§. 339. But immediately after the Porta lofes the Nature of a Vein 1 and Sinus, it divides into five large Branches, which are distributed into an infinite Number of others, which are still smaller, and disposed throughout almost every Point of the Liver, in such a manner that they at last escape the Sight, and compose the principal 2 Part of the Substance of this Viscus.

We here meet with a surprizing Alteration, not to be parallel'd in any other Part of the Body, namely the Conversion of a Vein into an Artery. The Vena Portæ is truly a Vein, till it is arrived near its Entrance into the Liver; but after passing through

through the Gates or Entrance betwixt the small Lobes of the Liver, it then becomes truly an Artery, without being first extended either to the Heart or Lungs. For, in the first place, it is covered with a muscular Coat, which always accompanies the Arteries, but is never found in the Veins. But yet there is some Difference in this Coat from the common Fabrick of that in an Artery; for every Artery puts off all that is muscular in its Tunics, fo foon as it has reached any Viscus: but, on the contrary, the Vena Portæ, which was before thin, acquires a muscular Coat in its entering the Liver. (2.) Besides this, it is usual for Arteries to divide themselves into smaller Branches, as it is for Veins to arise by small Beginnings, and to terminate or run together in larger Trunks, 'till they reach the Heart, without making new Divisions. But the Vena Porta divides itself a second time into Branches extended from its common Trunk. (3.) The Course of the Blood in Arteries is from the Heart into the smaller Extremities of the Vessels, and such is the Course of it through the Porta in the Liver. (4.) The Bile is secerned from the Vena Portæ, whereas Secretion is the Business of an Artery. (5.) Lastly, Every Artery is furnished with a corresponding Vein, which returns the Blood in a contrary Direction towards the Heart, from whence it was brought by the Artery: but all this is truly the Case with respect to the Vena Portæ, which returns the superfluous Blood after the Secretion is formed through the hepatic Veins into the Cava. The Vena Portæ therefore has all the Properties of an Artery; fo that it is from hence apparent, that the Ancients had some Reason for making two Sources of the Veins, the one from the Heart, and the other from the Liver.

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I keep by me a human Liver, which was happily filled with Injection through the Vena Portæ by Ruysch. If a Bit of this Viscus, which has been varnished with Oil of Turpentine, be viewed with a Microscope in the Sun's Rays, (without which it will not be fufficiently visible) there will then appear an infinite Number of small Vessels throughout the whole Particle, which is itself no bigger than a Grain of Sand; infomuch that you would be ready to swear, that the whole Substance of the Liver was composed merely of Branches from the Porta. The fame Appearance of Vessels may be also discerned by taking off the external Membrane from the Liver, shaking and dissolving a small Particle of it in Water. These Vessels therefore we may, for the take of Distinction, reasonably call the Arteries of the Sinus of the Vena Portæ.

§. 340. In the next place, the hepatic Artery i arising from the left Branch of the coeliac, enters the Liver near its Gates or Protuberances before-mention'd; and infinuating itself in the acquired Substance of the Capsule, it is distributed therein, and ramified throughout every Part of the Liver, infomuch that there is not the smallest Point without some Branch of it; and thus it not only spends itself upon the Capfule or Coats of the Porta in the Liver, but also ramifies itself through every Part; only as it does not stand in need of this Capfule, it does not fo closely invest or penetrate the fame in the larger Vessels. Besides the hepatic Artery, there are two others extended from the Diaphragm and suspensory Ligament, and inserting their Branches together with the former,

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e , former, they are at last joined by other small Branches which come from the cyftic Arteries themselves.

This Artery extends itself throughout every Part of the Liver, in which the Branches of the Porta are diffributed, even into the minutest Penicilli or Bunches of the Valcules; in which it is conspicuous, whenever the Arteries and Veins have been filled with Injection of different Colours. I keep by me some Livers injected by Ruysch, which feem to be in a manner composed of nothing else but the hepatic Arteries. But if the Vena Portz only is injected, it will quite compress and obscure the hepatic Arteries. These Arteries appear to the best Advantage when they are first injected, after the Blood has been washed clean out of all the Branches of the Vena Portæ, by the repeated Injection of warm Water. Gliffon has observed, that these Arteries do not penetrate the Capsule which bears his Name, but that it creeps on the Surface of that Capfule.

§. 341. But the Vena Cava tending upwards towards the Diaphragm, and infinuating itself into the gibbous Part of its Surface, does there receive three large Branches 1 coming from the Liver, which are inferted by distinct Apertures, and it also receives several smaller Branches; all which being composed of numberless minute Twigs dispersed through the whole Substance 2 of the Liver, do at length return into the Cava all the Blood which was conveyed to the Liver by the Vena Portæ; though those Branches of the Cava seem to be les

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less 3 both in Number and Size than those of the Porta.

In that Part where the Veins which come from the Liver into the Cava are inferted, we meet with a peculiar Sort of Pellicle, which is in effect a true Valve, moveable, and arifing from the right Angle, which the large hepatic Vein forms with the Trunk of the Vena Portæ, being rightly described by nobody but Winflow. This moveable or fluctuating Membrane admits the Blood returning from the Liver to enter into the Cava, but prevents the Blood of the last from returning back towards the Liver in violent Motions of the Body, when the Course of the Blood is accelerated through the iliac Veins towards the Heart, and by its Impetus might otherwise enter the Liver latterly: but thus it clofes the Mouths of the hepatic Veins, as it is inclined by the Weight or Impulse of the Blood, which is by this means prevented from returning out of the Cava into the hepatic Veins. Immediately above this Valve the Cava passes through the tendinous Circle of the Diaphragm, and immediately forms the Sinus of the right Auricle: for in the human Body there is no inferior Trunk of the Vena Cava in the Thorax as the Ancients imagined, the Truth of which is expressed with faithful Figures by Eustachius.

Wherever a Branch of the Vena Portæ terminates, there a small Twig or Circle of those Veins arise which belong to the Cava; nor is there so much as a single Grain of the Liver, in which there are not the Extremities both of the hepatic Artery, the Vena Portæ, together with the incipient Branches of the Vena Cava. I have some Livers by me filled by Ruysch with ceraceous Injection through the Vena Cava, which is indeed not very difficult

to perform after the Valve has been perforated with a Probe; and this way the Liver seems to be entirely composed of Branches of the Vena Cava. For when these only are filled, all the other Vessels are compressed into a very small Substance; insomuch that from hence arose that Diversity of Opinions among former Anatomists, some of whom affirmed the Liver to be composed only of the Veins of the Porta, and others only of the Cava; but the Ancients destined the gibbous Part of the Liver to be the Seat of the Vena Cava, and ascribed the concave Part to the Trunk of the Porta.

This has been truly demonstrated by Ruysch, in Opposition to Glisson and Malpighi: for after the Bile has been secerned the Humours which are returned by the hepatic Veins to the Cava must be

proportionably less.

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§. 342. Wherever the Extremities 1 of thefe two last mentioned Veins (§. 339, 341.) are joined together, they become fo extremely minute as to form furprizing fine Penicilli or little Bunches like Pencil Brushes disposed in Bundles, and these again are disposed so as to appear like little distinct Globes 2 formed of the almost invisible Vascules distinguished one from the other: but these globular Corpuscles or Bundles of the Penicilli very much resemble the Bodies which we call simple Glands; and these are collected together into little Lobes which unite again into larger Lobes, 'till they at length make up the whole Substance of the Liver. And that this is the Fabric of the Liver we are affured by the Inspection of it in Insects, Fish, Quadrupeds, E 3

and Birds, with the Formation of the Liver in these Animals before Birth; as also from the Diseases of the Viscus itself, and from what is manifested in it to the naked Eye by anatomical Injections.

Throughout the whole Substance of the Liver there is no Fat observed, notwithstanding the cel-Jular Membrane is there found, extending itself within the Capfula Gliffonii; and by making a fmall Wound it may be fo inflated that the Air will pass betwixt the Capsule and the Vena Portæ, so as to follow all the Ramifications of the latter. I formerly urged in Opposition to Ruyseb, that the Case of Hydatides seemed as an Argument to prove that the Liver was composed of Glands, inasmuch as the whole Liver had been several Times found by Anatomists composed almost entirely of watery Vesicles: to which Ruysch answered, that the cellular Membrane penetrated betwixt the Capfula Gliffonii and Veins of the Porta throughout the whole Substance of the Liver, which he had sometimes feen to contain Fat; and that therefore this Membrane might be fo changed in a Dropfy, that the Veffels being compressed by the confined Water might in a manner disappear, and render the whole Viscus apparently a mere Assemblage of Vesicles. And he affirms, that belides this fpungy or cellular Texture, he could find nothing in the whole Substance of the Liver but mere Bundles of Vessels.

<sup>2</sup> The Liver of a Hog nearly resembles that of a human Body; and this, as also the human Liver itself, being diligently inspected, has in its external Surface the Appearance of innumerable and scarce visible little Grains, which Malpighi took to be simple Glands. But Ruysch, by exquisitely filling the Vena Porta in human Livers, could find nothing

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nothing in these Grains but Penicilli, or Bunches composed of thousands of the smallest Vascules, which lying by the Side of each other, refemble the Appearance of the many fine Hairs in a Pencil Brush. He also found that these Grains, or feemingly fimple Glandules, separated by Maceration and shaking in warm Water into minute Penicilli of this kind; and adds, that he perceived in the Penicilli the ultimate and most minute Threads both of the Vena Porta, the Vena Cava, the hepatic Arteries, and the biliary Ducts. I have by me a Liver prepared with great Artifice, in which the biliary Ducts are injected with Wax; but the whole Liver looks red, and there is apparently a small Branch of the biliary Duct, with a small Artery and Branch of each Kind of the Veins affembled together in each of these Grains or Corpuscles, which are composed of the Penicilli, There has been a long Controverly betwixt me and Ruylch with regard to the Question, Whether the Liver is composed of Follicles or small Glandules, or else of mere Bunches of Veffels, without being wrapped up in diffinct Membranes? The former of which Opinions I defended; which was also the Opinion of Ruysch himself, until he afterwards changed his Mind.

§. 343. About all the forementioned glandular Corpuscles, or Bunches of smallest Vessels, (§. 342.) there appear small Ducts arising by an invisible Origin from those smallest Penicilli, or Bunches of Vascules (§. 342.): and these Ducts always accompany the Ramifications of the Porta, being invested in the same Capsule, to which they so firmly adhere, as to be scarcely separable; these smaller Ducts

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gradually

gradually uniting together into larger of the fame Kind, do at last end in one great Tube 2 at the Trunk of the Vena Portæ, which Tube or Canal is called the Porus Hepaticus, the hepatic or biliary Duct, into which Duct a Humour very different from the Blood is received, and afterwards discharged under the Denomination of the hepatic Bile 3 (§. 340.)

In every fensible Point of the Liver, there is a Conjunction of three distinct Vessels, namely, a small Branch of the Vena Cava communicates with the corresponding small Branch of the Vena Porta, and betwixt the Union or Anastomoses of these Vessels arise small Ducts of the Liver, whose Branches unite together, and all the way accompany the Branches of the Vena Portæ, as Gliffon has long ago observed: for by injecting Ink into the biliary Duct, he traced the Course of the Vesfels from the Porta through all Parts of the Liver. But the Origin or Rise of this secretory Duct from the meeting of the two Veins, feems to be much after the nature of the fmallest Follicles (§. 242.) into whose Cavity the Bile is separated from Arteriolæ affembled together in the Form of a Pencil Brush; from whence the Bile is conveyed by a fmall Radicle of the Ductus Hepaticus, by an Assemblage of which Radiclés, collected into one large Trunk; is formed the Ductus or Porus Hepaticus. For it does not feem reasonable that the Bile should pass immediately from the Arteries into the Veins; fince this is opposed by the Instance of the Urine (§. 352.), which is distilled through the urinary Ducts, collected together into about twelve pyramidal Bundles, a thousand of which are found opening in every Papilla, which difcharge

charge the Urine into the last Follicle or Pelvis of the Kidney. But this is not all; for there is a fecond Emissary, the Ureter, which receives the Urine from the Pelvis, and conveys it into the general Follicle belonging to both Kidneys, namely, the Bladder; from whence it is at length discharged out of the Body by the Urethra, which makes

a third Emissary.

This is collected in the Sinus of the Porta, and is composed of five principal Branches, but yet it does not follow the large Vein of the Porta, but runs in a direct Course to the Duodenum: and this is the excretory Duct of the Liver, which is fingle and discharges the Bile separated by the Fabric of the Liver. But the Lymph and Blood which remain superfluous after the Business of Nutrition, are returned by the Vena Cava, and the Lymphatics to the thoracic Duct, and are in nothing different from the Blood and Lymph of any other: Viscus.

Which is mild, fweet and watery; (§. 98.) for it is secerned in the Liver, of a very mild Taste in all Kinds of Animals.

§. 344. Considering the Fabric 1 of the Vena Portæ (§. 338.) and Vena Cava (§. 341.) with the Pori Hepatici (§. 343.) it will appear from thence and from confidering the Motion of the Humours propelled through. the Vena Portæ, (§. 337.) with the Nature of the Juice contained in the Pori Biliarii, and from anatomical Experiments made by tying 2 and dividing 3 the Duct fo as to collect the Bile, I say it will from all these Particulars appear, that a Juice 4 is separated from the Blood of the Vena Portæ 5 in the smallest Extremities

of that Vessel, which is conveyed soon after by the Branches of the Pori Biliarii through one large Canal out of the Liver; while the Blood remaining after the Secretion returns by the Branches of the Caya from the Liver towards the Heart 6.

So that the extreme Branches of the Vena Portæ terminate either in glandular Follicles, or in vascu-

Iar Penicilli. (§. 342.)

If the Vena Porta is constringed with a Ligature in a living Dog, the Secretion of the Bile will by that means be totally suppressed in a sew Hours time. But if the Ductus Hepaticus be constringed with a Ligature out of the Liver, a Tumor is then formed betwixt the Liver and the Ligature, while the Duct remains empty and collapsed, betwixt the Ligature and the Intestine.

If the hepatic Duct is divided in a living Animal, the whole Cavity of the Abdomen will in a little Time be filled with extravasated Bile from

the Liver.

Not derived from the Vena Cava as many of the Ancients supposed; for the Valve or Membrane mentioned (§. 341.) is an Obstacle which permits the Blood to return from the Liver into the Cava, but prevents it from passing from the Cava into the Liver. This Valve or Membrane has been formerly delineated by Eustachius and Vesalius.

In great plenty, as is evident from the large Bulk of the Liver, and Capacity or Diameters of the Branches of the Vena Portæ, as also from the Calculations of Borelli, and from the Experiments of Nucke. This last Anatomist opened the Abdomen of a living Dog, extracted the Duodenum, and made a Ligature upon the hepatic Duct, at a

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small Distance from the Intestine; beyond the Ligature he inserted a Quill into the Duct, which he sastened by proper Ligatures, so as to come out of the Abdomen, while all the other Viscera were retained in their proper Places. Thus he made a continual Discharge of the hepatic Bile, which he collected to the Value of several Ounces in a few Hours time. There is certainly nothing more useful and entertaining than Experiments made on living Brutes, which inclined me to be frequently present at the Experiments of Nucke; in which Branch of Knowledge I should certainly have spent more Time, if other Business had permitted.

Namely, the Blood of the Vena Portæ which returns to the Heart. For the Liquors injected by that Vein return through the Cava; but the hepatic Artery being injected does not fill the Vena Cava, which Artery seems to have those Branches of the Vena Azygos for its fellow, whose Branches Eustachius discovered passing to the Liver. But the Passage of the Blood from the Porta into the Cava is also demonstrated by a Ligature, made upon the Vena Cava at the Diaphragm, where-upon the Liver becomes so turgid as to almost burst

in the middle.

§. 345. Which Secretion of this Viscus is also rendred still more evident from the Distribution of the hepatic Nerve; which, like the Artery, ramifies and accompanies the Vena Portæ throughout all its Divisions.

Which Nerves coming from the eighth Pair, and from the Intercostal, are divided so as to accompany the Capsula musculosa Glissonii throughout every Point of the Liver, and seem as it were to animate this muscular Fabric, that the Blood which

which here receives little or no Force from the Heart, nor yet from the Arteries, might be capable of passing through the converging Vessels of the Liver. Which Nerves also, besides their Necessity for all muscular Action, seem to discharge some of their Juice, as well in the Liver as in the other Viscera.

§. 346. Now in the human Liver 1 there is a small oval Bladder fixed 2 in its concave Part, for receiving the Bile; which Bladder. being composed of an infinite Number of Vessels of all kinds interwoven, is pretty capacious, and terminates in a spiral or contorted Duct 3 wrinkled on the Infide, which is called the cyflic Duct, fituated in fuch a manner, that its Neck and narrow Part lies higher 4 than the bottom of the Cyst; which Neck being continued to the Porus hepaticus, which it meets in an acute Angle 5, they both together unite, and form one common Duct, larger than either the hepatic or cystic Duct alone; which common Duct descending, enters the external Coat of the Duodenum at an acute Angle; and after descending a little way betwixt the external and the next Coat, it foon perforates the fecond, and passes a confiderable way betwixt that and the third Tunic; after which, it opens freely by a round Aperture into the Cavity of the Intestine; from whence we learn, that the Bile can be discharged this way into the Intestine, not at all times 6, or under all Circumstances, but

only when the Intestine is relaxed, but not at all when its Coats are strongly contracted?

Animals which are exercised with hard running, such as the Dromedary-Horse, Stag, Range-Deer, and many of the Fish kind, have no Gall-Bladder; but instead of that, they have various Ducts disposed in an extraordinary manner. In other Animals again, there is a Gall-bladder, but placed at a Distance from the Liver, as in the

Cat, Tiger, &c.

2 In fuch a manner, that a large Part of the Gallbladder, even almost the half, is buried in the Substance of the Liver. But its Posture is such. that in erect People the bottom is lowermost, at which time nothing can pass out of the Gall-bladder unless it was quite full. It is also covered with the common Membrane of the Liver, which is continued from the Peritonæum, being very thin, and full of fmall Vessels. The other Membrane of it is thicker, and in a manner muscular; but yet it does not feem to have any fuch Action of corrugating, like that of the urinary Bladder, fince half of the Vesicula Fellis is firmly attached to the Liver; and therefore its chief Use seems only to be for preventing too great a Dilatation of this Receptacle. There are an infinite Number of Bloodvessels in its Texture, and the Arteries are disposed in a peculiar manner, fo as to induce one to imagine that they must have some particular Use more than common. Its Capacity is usually about two Ounces; but in acute inflammatory Diseases, it is furprizingly diffended, as was observed in the epidemic Fever of the Year 1727: and in these Cases it has been found to contain fix or eight Ounces.

This spiral Valve has been well observed by Nucke, and his Pupil Reverborst. This Valve

prevents the Bile from passing easily either into or out of the Vesicula Fellis; so that it is retained in the Gall-bladder, 'till some additional Pressure affists to overcome the Resistance of the Valve. But both the cystic and common Duct pass under a Membrane, which is continued from the Gall-bladder to the Duodenum.

For People generally either fit or fland erect, and in that Posture the Neck of the Gall-bladder will be uppermost: but in a supine Posture it will be lowermost; from whence it is evident, that the Bile will be sometimes retained, and sometimes ex-

pelled alternately.

From hence it happens that nothing can pass out of the hepatic into the cyflic Duct, unless the Bile meets with a greater Refistance in the common Duct than that which arises from the Angle of the cystic Duct; and, on the contrary, that nothing can pass out of the Gall-bladder towards the Liver, unless the common Duct gives a greater Relistance than that which arises from the Angle of the hepatic Duct. Therefore for the Bile to pass out of the Gall-bladder either to or from the Liver, supposes some additional Force more than natural, and has occasioned some to imagine that neither the Bladder had its Bile from the Liver. nor that the Liver received any from the Gallbladder; since if this had been the Intention of Nature, she would have conjoined the two Ducts at right Angles. Wonderful Disputes have arose concerning this Motion of the Bile, especially about the Time when Helmont and Sylvius published their Writings upon this Subject. But the Generality, with Gliffon, will have the Course of the Bile to be from the hepatic Duct into the Gallbladder: To which it is objected, that if this had been the Defign of Nature, she would have made the

the Course more open betwixt the two Ducts. But whatever was the Design of their Conjunction, it was evidently to produce a Mixture of the cystic and hepatic Bile in the common Duct.

In Men the Gall-bladder is never observed to be full, unless in a diseased State; but it is so far empty, that it will usually hold about a third Part more of any Liquor. But after long fasting this Receptacle becomes very turgid in all Animals. I once saw the Gall-bladder thus distended in a fat Hog, which had not been sed for three Days, and the Neck was so much contracted by the Distention of the Coats, as not to allow one Drop to be expressed.

Nothing can pass into the common Duct from the Intestine, since nothing can be applied within the Intestine to dilate the Mouth of this Duct, but what will at the fame time obstruct it more powerfully, as it endeavours to dilate it more violently. But neither can the common Duct of the Bile difcharge itself under all Circumstances; for when the Intestine is violently contracted with a convulfive Force, it affords no Admittance to the Bile: and it equally denies a Paffage to the Bile by thurting up the Mouth of the common Duct, when the Intestine is too much distended by a Flatus; from both which Caufes, the Bile may be forced to return back into the Liver and into the Cyst in a different manner to what is usual in the natural or healthy State of the Parts. An Obstruction of the Bile, and its Confequences, have been observed, as well from a Diffention of the Intestines as from Poisons; by the Action of which last, the Stomach has been diffended with Wind like a Pair of Bellows: And this was the Case also in the epidemic Fever lately mentioned, in which no Wind could

be discharged; from which Causes a Jaundice may soon follow in various Degrees.

- §. 347. From an bydraulic 1 Confideration of this Fabric of the Liver (§. 346.), compared with what was faid before (§. 344.), it will very evidently appear, that a Humour is conveyed from every Point of the Liver and Gallbladder through the common Duct, into that Part of the Intestine, by a natural Aperture, where the Chyle is most retarded for the first time, after it has been expelled from the Stomach: And this is still more evident, because when the Gall-bladder has been fometimes found absent 2, its Place has been supplied with many small biliary Receptacles, formed of an Affemblage of the biliary Ducts, so as to discharge the Bile into the Duodenum by many fmall Canals.
- Namely the Vena Portæ carries the Blood into the Liver, where it deposits the biliary Juice through the Ducts of the Vessels which form the Penicilli, into the Cavity of their Follicles; but from these Follicles the Bile is received into the Pori or Ducts, whose Numbers are infinite; but are all of them at length collected into one common Duct, which receives also the cystic Bile, and mixing it together with that from the Liver, conveys the mixed Bile into the Duodenum. This is the general Course of Nature; but the other Courses which the Bile sometimes takes, are preternatural.

There have been many cystic Ducts observed, which did not open into the hepatic, but inserted themselves separately into the Duodenum; in which

which Cases the Bile certainly never passed from the hepatic into the cystic Duct.

8. 348. We are in the mean time taught by Experiments, that there is an open and easy Paffage from the Cavity of the Gall-bladder into the Liver, the common Duct, and into the Cavity of the Intestine 1, as also from the Liver 2 by the Ductus Hepaticus into the cyftic Duct 3 and the Bladder itself, as well as into the Intestines; and lastly, that there is a like Paffage from the hepatic into the cyftic Duct, and from the cystic into the hepatic. Comparative Anatomy also informs us, that in fome Animals the Gall-bladder is wanting, as in Horses; and in others, that the hepatic Duct discharges its Humour 4 into the bottom of the Gall-bladder: We also know, that the hepatic Bile is plainly different 5 from that contained in the Gall-bladder (§. 98.) From all which it appears that the hepatic Bile (1.) tends naturally downwards 6, (2.) fometimes 7 into the Gall-bladder; (3.) fometimes also being preffed back into the Liver 8, it enters the Vena Cava, and flows all over the Body; (4.) that by stagnating in the Gall-bladder, it acquires 9 the Properties of cystic Bile; (5.) that perhaps a Portion of the bitterest Part of the cystic Bile may arise from the small Glands 10, seated in the Membranes of the Gall-bladder, and supplied by the cystic Arteries, in the same manner as in the Membrane which lines the auditory Passage; (6.) that this mixes 11 with the

the hepatic Bile flowing into the Gall-bladder itself.

If all the biliary Vessels remain in their natural State, and a Pressure is made either upon the cystic or hepatic Duct, the cystic or hepatic Bile will then constantly slow into the Duodenum; and if either of the aforementioned Ducts are tied with a Ligature, they will appear turgid betwixt the Ligature and the Liver or Gall-bladder, but quite empty betwixt the Ligature and the Duodenum.

If the common Duct of the Bile is tied, and Urine or Water is injected into the Gall-bladder, after it has been first tinged with some Colour, that Water or Urine will flow into the Liver thro' the hepatic Ducts. This Course is not natural, but only that which the Bile takes, when the Resistance at the common Duct is greater than to-

wards the Liver.

3 If the common Duct be tied, and a Pressure made upon the hepatic Duct, the Bile will then run into the Ductus cysticus and Gall-bladder, so as to fill the latter till it is almost ready to burst.

4 In such a manner that the hepatic Duct is not connected with the cystic, but inserted into the

bottom of the Gall-bladder.

We have frequently observed before, that the hepatic Bile is mild, and that of the cyst very acrid, as consisting of a rancid Oil render'd extremely bitter; and therefore there is a considerable Difference

betwixt the cystic and hepatic Bile (§. 98.)

observe this general Rule, namely to convey their Juices from a larger to a smaller Capacity, unless some particular Obstacles should intervene. If therefore we compare the common Duct with the hepatic and cystic, we shall find the former less

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than the two latter; besides which Difference in the Capacity of the Ducts, there is little else that can determine the Course of the Humour that way from the Gall-bladder upon the Addition of any Pressure. It therefore remains as a general Rule, that the Bile must flow from the smaller hepatic Ducts into the larger, and from thence into the Ca-

vity of the Intestines.

<sup>7</sup> I cannot indeed conform to the Opinion of Glisson and Raw, who supposed all the hepatic Bile was first poured into the Gall-bladder: but I only affert that the hepatic Bile flows back into the cystic Duct, whenever there is an Obstacle or Relistance made in the common Duct, whether that Obstacle proceeds from a Calculus, Flatus, a spasmodic Constriction of the Intestine, from an Acid, Inflammation, or any other Cause obstructing the Course of the Bile into the Duodenum; and that the Gall-bladder is filled under these Circumstances is evident to the Eye, by making a Ligature upon the common Duct in a living Dog. In general, there is a free Communication betwixt the Gallbladder and any other Part of the Liver; as also betwixt every Part of the Liver and the Gall-bladder; so that the Bile may pass either from one to the other either way, according as one Course may be more easy than the other.

8 It appears from Experiment, that by injecting a Liquor through the common Duct, it enters the hepatic Duct, the Gall-bladder, the whole Liver, and even it fills the Vena Cava itself. This is confirmed by innumerable Observations. In every new born Infant a Jaundice follows sooner or later, and the intestinal Fæces are discharged white and like Cheese, while the Skin itself is tinged with a yellow Colour: If now Syr. de chicoreo cum rheo be exhibited, or Venice Soap given from five Grains

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to half a Dram with Lap. Cancrorum, the Skin will then by degrees whiten, the Fæces will turn yellow, and the Jaundice will be removed. In this Case it is easy to perceive, that from the Milk turning fowre in the Stomach, a Coagulum is formed, which being propelled into the Duodenum, stuffs up that Intestine and obstructs the Mouth of the common biliary Duct; fo that the Bile is obliged to regurgitate into the Liver and Vena Cava, and mixing with the whole Mass of Blood, it tinges the Skin of a yellow Colour; but after removing the obstructing Coagulum which prevented the Bile from passing into the Intestine, all the Symptoms then disappear. But the thing will appear still more evident from the bilious Cholic of Sydenbam, which that just Writer has very well described, but did not understand that the Seat of it was in the Liver. They who are taken with this Difease are oppressed with intolerable Anxieties in the Præcordia beyond Expression, which are followed with Pains and Convulsions in the Abdomen, with so severe a Cholic, that the stoutest Man who little fears any Disorder is obliged to fill the whole Neighbourhood with his Cries from the fevere Torture of the Disease. After the worst Symptoms fudden Rest follows, and the Patient forgets all his Pains in Sleep; but after Sleep the Urine is voided of a Saffron Colour, and the whole Skin appears yellow, with a fort of Weakness throughout the whole Body. This Colour of the Skin degenerates by degrees into a black, and after a few Weeks Time vanishes; so that the Patient seems to be well, but the Signs are unfaithful, for the Diforder with which they were before tormented, returns and again goes off, and thus alternately; in which manner they are tormented at Intervals, 'till they are exhausted and wasted away. Upon

Upon opening the Bodies of these Patients after Death, the common Duct of the Bile is generally found obstructed with small Stones, the Duct itself appearing furprizingly dilated, infomuch that it has fometimes equalled the Vena Portæ. And this is the History of the Disease and its Course, namely, an Obstruction in the common biliary Duct, which prevents the Bile from being conveyed into the Intestines, whence it is by degrees accumulated, fills and diftends the Gall-bladder and cyftic Duct to fuch a degree as that they are ready to burft, and have been fometimes feen capable of holding a Pint; from hence arise those surprizing Anxieties of the Præcordia, which therefore by the Confent of the adjacent Parts, brings on a Convulsion of the abdominal Muscles and Diaphragm, which causes vomiting, &c. By the various Endeavours or Strainings to vomit, the Bile is at length drove back through the hepatic Ducts into the Liver and Vena Cava; in confequence of which, the Blood and whole Skin are tinged with a yellow Colour, the biliary Ducts are then fet at Liberty from their over Distention, and all the Torments are eased; but more Bile being by degrees separated and accumulated as before, the biliary Ducts are again diftended fo as to cause a Return of the former Pains and Convulsions: after this a second Criss follows, and the Bile is repelled into the Vena Cava, fo as to infect the whole Mass of Blood. But the Reason why a Dropsy follows is, because the Bile ferves like a natural Soap to attenuate the Chyle and diffolve its Viscidities so as to appear uniform; therefore when this is mixed with the Blood, it dissolves the fame into a mere Water. But that the Bile does pass into the Blood is demonstrated even by the Eye with a Microscope. I have often viewed the Eyes of People in a Jaundice with

with a Magnisser, and have perceived that the yellow Colour of the Adnata Tunica arose from the Bile which was not discharged into the Intestines, but returned into the Blood, whence the Skin appeared yellow, and the Fæces were discharged of a white or ash Colour. The like Disorder seems to arise from certain Poisons, from whence Convulsions follow, by which the Orifice of the common Duct of the Bile being violently contracted, a Vomiting and Jaundice ensue, but such as soon terminate in Death. Thus those who have been bit by a Viper, suffer excruciating Pains with a convulsive Motion in the Hypochondria, and within two or three Minutes time the whole Skin turns yellow.

9 All fat Aliments, fuch as Butter, Lard, the Livers of Fish, &c. are very relishing and sweet while recent or fresh, and are so mild as not to offend even the naked Eve, or a Nerve which has been laid bare; but if those Substances are taken in a larger Quantity than is capable of being digested by the vital Powers, they grow bitter, rank, yellow, rife up into the Throat, and are spit out in the Form of Oil, which is inflammable. Thus it is evident, that the sweetest Oils may be so altered by stagnating with the Heat of the Body, that they appear to be of a very opposite Nature. The fame Alterations doubtless arise in the oily Bile of the Liver, after it has stagnated some time in the Gall-bladder. For I have experienced that the hepatic Bile is sweet to the Taste, and it is even fweet when it comes to the Gall-bladder, provided there is no Mixture of the cystic Bile; for nothing is more agreeable than the Livers of Fish, which nevertheless have the Bile in the Gall-bladder exremely bitter.

licles in the Skin of the Auditory Passage, being

at first thin and insipid, serving to anoint the neryous Membrane which is fo extremely fenfible. and to defend it from the Injuries of the external Air; but the same Cerumen or Ear-wax, which was infipid after the Parts had been well cleanfed of a mild and fluid Confistence, does by standing only inspissate, turn yellow, and become extremely bitter. But there are the like cerumenous Follicles, fo called by Nucke and Ruysch, seated in the Membranes of the Gall-bladder; and by these Follicles the Bile is separated from the arterial Blood more acrid, bitter, and truly faponaceous, which being diluted by the hepatic Bile, forms a Lixivium extremely well adapted to diffolve Vifcidities, and reduce the gross Parts of the Chyle to Therefore there feems to be an uniform Fluid. two Kinds of the cyflic Bile; the one venal, brought from the Liver by the hepatic and cyftic Duct, which by standing becomes more bitter; the other arterial, being formed in the Follicles of the Gall-bladder itself, and so extremely bitter, that one Drop will tinge a thousand of Water with a very remarkable Bitterness.

of the Duodenum and Colon, and being intimately mixed with the Chyle, occasions the Fæces to be afterwards discharged of a yellow Colour. But yet the Bile does not always continue mixed with the Chyle, which is always found white and sweet in the lacteal Vessels: nor does it perish with the Fæces, which have also no Bitterness; it therefore follows, that the principal and most laxivial Part of the Bile is absorbed again by the mesenteric Veins, and returned to the Liver, to be there separated again; from thence to be sent to the Intestines, to be there again absorbed, and thus to

repeat its Course many times.

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§. 349. All

§. 349. All that has been here advanced, is confirmed by the Discoveries of Glisson, Verbeyn, and Perault, who have observed numerous Duets I running from the Liver and porous Hepatics, to their Insertion into the Gallbladder, into which they continually discharge the Bile.

These are very well described in the useful Treatise of the celebrated Perault. The industrious Du Verney dissected various Animals with great Artisice in Company with Perault, who delineated what Du Verney discover'd, as being very skilful in the Art of delineating.

§. 350. From all which (§. 338 to 349.) the following Deductions appear to be true; 1. That the hepatic Artery 1, and its particular Distribution (§. 340.), is extremely serviceable towards Life, Nutrition, and Heat, contributing also to the Propulsion 2 of the hepatic Humours, as well as to their Secretion and Expulsion, for which Purpose it is wonderfully distributed through the very fine external Membranes of the Liver. 2. That from the Extremities of this Artery, there are great Numbers of Lymphatics, which are at first invisible in the Liver; though from these are formed the visible Lymphatics 3, which do not discharge themselves into the Vena Portæ, but into the Receptacle of the Chyle at the Loins. 3. That there are Veins 4 which receive the superfluous Blood from the hepatic Artery, after the Lymph has been thus feparated; ted; which Veins convey the remaining Blood into that Part of the Vena Azygos, which is below the Diaphragm. 4. That all the Vifcera of the Abdomen, which are subservient to Chylification, fuch as the Spleen, Omentum, Stomach, Pancreas, Mesentery, Intestines, do all in some measure serve the Liver 5. by supplying it with their venal Blood after it has been wonderfully changed in each of those Viscera. 5. That Veins may be so altered, as nearly to resemble 6 Arteries, as well in their Make and Strength, as Uses. 6. That Secretion 7 may be made from the venal Blood. 7. That a Portion of the Blood propelled by the Heart, becomes twice 8 arterial and twice venal before it returns again to the Heart. 8. That the Course of the Humours in these intermediate Vessels is extremely weak and flow 9. 9. And therefore it was necessary for the Liver to be seated near, and attached to the Diaphragm. 10. Whence it is easy for Stones. glutinous Concretions, Worms, Sordes, and the like, to be formed or generated about this Viscus in those who neglect the proper Exercifes 10 of Body, from whence arise a large Train of Diseases. 11. That the whole Office of the Spleen 11 is to be subservient to the Liver in the Formation of the Bile. 12. And from thence arises the Affinity and Dependance 12 of the Diforders, which follow in one Part from those of the other; as also with respect to the healthy Condition of one depending on that of the other. 13. That the Mat-

ter 13 of the Bile has a different Origin from that of all the other Humours, as is evident from a chemical Analysis. 14. That there is here a very particular Kind of the Blood's Circulation 14, the like of which has never yet been discovered in any other Part of the Body. 15. That there is a fort of Similitude betwixt the Sinus of the Vena Portæ and the Heart 15 with respect to their Action; as also betwixt the five Branches of the same Sinus, and the Arteries which arise from the Ventricles of the Heart. 16. That the Cure of topical 16 Diforders is in no Part more difficult to perform than here. 17. And yet that there are not fo many Viscera, Vessels, Tumours, and Causes employed 17 towards the Formation of any one Juice besides in any Part of the Body, as we here see concur for the Production of the Bile. 18. Which must therefore be one of the most useful, extensive, and efficacious Means towards the Conversion of our foreign alimentary Juices into the Nature of nutritious animal Fluids 18. 19. And that therefore the Bile is no Excrement 19. 20. But that there are at least two Kinds of it. 21. And finally, that the Liver operates more immediately for the Formation of the Chyle than of the Blood, and therefore may be rather 20 esteemed one of the principal chylificative, rather than a fanguificative 21 Organ.

It by no means feems probable, that so small an Artery should carry so large a Quantity of Blood into the Liver, as is required for this Separation

ration of the Bile; and therefore the hepatic Artery feems to be given to the Liver, as the bronchial Artery to the Lungs, namely, to nourish the folid Fibres of the Liver; for which Purpose it was therefore necessary it should be distributed throughout every Point of the Liver, fince the venal Blood does not nourish: Hence it is that all Parts of the Body which receive and transmit the venal Blood, are not nourished by that Blood, but by particular Arteries of their own, as in the Heart, Lungs, and Liver. Hence it is that a Liquor being injected by the hepatic Artery, neither returns by the Vena Cava, nor through the Pori Biliarii, being wholly spent in the solid Fibres of the Liver. But if the Vena Portæ be injected, the coloured Liquor foon flows into the Vena Cava, and into the Póri Biliarii.

The Blood of the Vena Portæ is the most remote from the Heart, and is therefore the coldeft: nor is it capable of acquiring Heat, because it is destitute of that Attrition and Friction of the Arteries, from whence only the Heat of the Blood arises. The hepatic Artery therefore in some meafure warms the cooler Blood of the Vena Porta. But as Veins are destitute of all Pulfation, therefore the Arteries are generally disposed by the Sides of the Veins, that by their continual Pulsations the more fluggish venal Blood might be drove forward: and this Action is fo confiderable in the hepatic Artery, that from thence the Ancients imagined that there was a Pulfation in the Vena Portæ itself. It is worth Observation, to see how exactly Eustachius has figured the Arteries and Veins accompanying each other; which is no lefs true in the Liver, where every Branch of the Vena Portæ is followed by the hepatic Artery, in the fame manner as the Emulgents and Branches of the Cava, accompany each other very exactly. This Concourse of the hepatic Artery and Vena Portæ throughout the Liver, was long ago observed by Glisson, who injected them with Ink; but they have been since more evidently demonstrated by the more accurate Injections of Ruysch. These are therefore the Reasons why the hepatic Artery does not extend itself beyond the Bounds of the

Capfula Gliffonii.

3 If a Ligature is made upon those Vessels by which the Liver communicates with the rest of the Body in a living Dog, while yet breathing, namely, upon the mesenteric Vein, you will perceive the whole Surface of the Liver, with its suspensory Ligament and the adhering Omentum, fpread on all Sides with lymphatic Vessels; and upon removing the Ligature they all fuddenly disappear. Bilfius perceiving this, thence deduced an Hypothesis, that the Lymph was prepared in the Liver, and from thence arose great Disputes in Germany, Denmark and Holland. But there is no great Difficulty in reconciling those Controversies; for all the Vessels of the human Body are not fanguiserous, fince there are an infinite Number of different Kinds. all whose Diameters are so small as to exclude the red Parts of the Blood: it was therefore necessary for as many different Humours to be prepared, as there are Classes of Vessels to be filled. Some of these more subtle Juices are spent in nourishing the Parts, while the rest return to the Heart for the future Uses of the Body, to which they are de-There must therefore be as many Orders of Veins, as there are Series of Arteries. the fuperfluous Parts of these more subtle Humours which were brought for the Nutrition of the Liver by the hepatic Artery, divided into the smallest Branches, are returned by the lymphatic Vessels

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of the Liver, which discharge into the Receptacle of the Chyle whatever redundant Humours they absorbed in the Liver; in the same manner as the more subtle Humours return from the Parts of the Thorax into the thoracic Duct, as also those from the Head are discharged into the internal jugular Vein and its Sinus. There is therefore nothing peculiar to the lymphatic Vessels of the Liver, more than what we observe in the other Viscera.

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4 As the Liver is furnished with a peculiar Artery for its Nutrition, so it has also small Veins corresponding to that Artery, which pass from the external Surface of the Liver to the Vena Azygos, or else to the Vena Cava under the Diaphragm, which Veins we find described in Bartbolin. I have myself observed Veins corresponding to the bronchial Artery, passing out of the Lungs in their back Part towards the Vertebræ, and terminating in the Vena Azygos in living Dogs. And that the fame Mechanism obtains in the Liver we may readily believe; for the external Membrane of the Liver is a Continuation of the Peritonæum, which involves the Intestines, Gall-bladder and Liver itself with the lower Surface of the Diaphragm, whence the abdominal Viscera are not contained in the Peritonæum as in a Cavity or Bag, but as it were wrapped up in a Cloth, forming a diffinct Bag for each Viscus. By inflating under the external Membrane of the Liver, you may press the Inflatus so as to make it run over all the Surface of that Vifcus, and even round the Gall-bladder and Diaphragm itself. But the Vena Azygos is lodged under this fame Production of the Peritonæum, in which the Viscera are confined, and therefore the shortest way from the Surface of the Liver is for the Blood to pass into that Vein. But no Anatomist Anatomist takes any notice of this Communication betwixt the Vena Azygos and the Liver, except Sammichelli in Bartholin as before mentioned. But the same Mechanism also takes place in the Intestines; for even in them the Blood which was brought for their Nutrition does not return through the Vena Portæ, but by Veins leading into the Cava, which are of a different Make, Disposition and Termination, as Ruysch acquainted me in his private Letters, soon after he made the Discovery, and as he has since publickly described.

For even the Liver, Gall-bladder and Pancreas are all subservient to one Intestine the Duodenum, since the hepatic Bile, and the more bitter cystic Bile, together with the salival Juice of the Pancreas, are all poured into and mixed with the

alimentary Mass in that Intestine.

<sup>6</sup> The Branches of the Vena Portæ in the Liver are in effect real Arteries, they only want the Pulfation: nor am I positive whether or no the strong muscular Capsule of Glisson does not in some measure endow them with a vibratory Motion.

<sup>7</sup> This is the only Instance that we are acquainted with, of Secretion made from the venal Blood; though Raw also suspected, that there was something of the same manner of Secretion made in the

Deposition of the Medulla of the Bones.

Namely, the Blood of the coeliac Artery, and the two Mesenterics, are discharged after the usual manner into the corresponding Veins; that is, into the Branches of the Vena Portæ, in which the Blood does not pass as usual towards the Heart, but is conveyed by a particular Mechanism to the venous Sinus of the Porta, where it becomes arterial again a second time, passing through the smallest converging Vessels of the Liver; after which it returns towards the Heart by Branches of the

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Vena Cava, in which Course it becomes a second time venal. Hence we may observe, that Harvey ought not to have absolutely laid it down as an Axiom, that the Blood's Circulation is from the Heart through the Arteries into the Veins, and so to the Heart again; for this Canon or Rule does not hold universally true, unless we except this

Mechanism in the chylificative Organs.

9 The Fabric itself of these Vessels demonstrates the Slowness of the Blood's Motion. Blood of the Vena Portæ loses almost all the Force which it received from the Heart, in its Paffage from thence through the Extremities of the Arteries opening into this Vein; in the fame manner as the venal Blood throughout the whole Body is fent back to the Heart almost entirely by the Motion of the Muscles. But there is not an easy Pasfage towards the Heart allowed to this Blood, fince it is to overcome a fecond Refistance, namely, the converging or arterial Extremities of the Porta in the Liver, which it would never be able to overcome, if it was not to be forwarded by the strong Action of the Diaphragm and abdominal Muscles in Respiration, by which the Compages of the Liver are compressed and agitated. I formerly (Anno 1696) spent some time with my Friends in diffecting living Dogs, in which upon opening by an inftantaneous Incision, I found the mesenteric Veins extremely small, but they seemed by degrees to enlarge, and at length they became quite varicose and extremely turgid. This Appearance may be eafily explained, inafmuch as the Blood of the Vena Portæ is not drove forward in its Vessels without the Assistance of a Compressure from the Muscles of Respiration; and therefore this Pressure being removed by opening the Abdomen, the Blood will not pass so freely through the Liver

Liver as before, but will be gradually accumulated, fo as to diftend the Veins which are used to discharge themselves into the Sinus of the Portæ; for I look upon the Pressure which is returned by the Peritonæum upon the Veins of the abdominal Viscera, by the alternate Contraction of the Muscles, to be as a kind of secondary Heart, to urge forward the Blood of the abdominal Viscera.

10 The learned Part of the World daily experience this Truth to their great Mortification; for many of them eat as much as a Ploughman, but do not digeft it with the fame Powers: for while the Rustic is employed upon his laborious Exercifes, the studious Person sits down to his beloved Study without the least Motion of Body, while his Respiration is extremely slow, or scarce perceptible, and his Body inflected towards the Books. Thus by degrees fooner or later the Studious become hypochondriacal, unless they set apart a few Hours for walking and Exercise before Dinner upon an empty Stomach, or else addict themselves to fome innocent Labour. The same is also true with respect to those who have the Administration of public Affairs, who live richly and plentifully, but are long confined to their Chambers, meditating with the strictest Attention of Mind upon the Affairs of others, which are made their own Con-But Rest is equally destructive to Brutes, as well as the human Species: and it is no uncommon thing to find the Livers of Sheep fo far eat up by a Swarm of little Fish called Flukes, that there is nothing left but its external Membrane like an empty Bag. And this more especially happens to those tender fibred Animals after the Now in these Animals the autumnal Rains. Mouths of the lacteal Veffels feem to be fo far relaxed, as to admit the Ova of these Insects; at which

\$ 350. which we need not wonder, if we confider that it appears from the Observations of Lewenboec, that an Infect equal to the hundredth Part of a Grain of Sand, lays three thousand Eggs within the short Time that it remains under the Inspection of the Eye by the Microscope. Even the Liver has been observed to be thus eat up by Insects in the most voracious of Animals the Lion. But in the Oxenkind, after refting the whole Winter, all the biliary Passages are lined with a stoney Crust: for the Bile being one of the most viscid of the animal Juices, is fcarcely moved of itself, unless urged forward by the Efficacy of Respiration; and therefore by the Winter's Rest, it concretes or conden. fes into a folid friable Mass. There are in short two Viscera, on which almost all chronical Diseafes depend, namely, the Lungs, from whence a Tabes and its various Confequences; and the Liver, from whence the innumerable Train of flow, or chronic Diforders.

"The Spleen, as we observed before, is to prepare the Blood fo as to be very dilute and fluid, in some measure to correct the slow Motion of it

through the Vena Portæ in the Liver.

Thus any one of these Viscera being obstructed, the rest partake of the Disorder: from whence it is that a Disorder in these Parts has by the Ancients been called of the hypocondria, or hypochondriacal, in relation to all the Parts feated immediately below the false Ribs, without any Distinction of the Liver, Spleen, &c.

<sup>13</sup> The Matter of the Bile is neither an alcaline fixed or volatile Salt, but an Oil attenuated with a small Quantity of Salt, so as to resemble a kind of Soap; which is extremely bitter in the Gallbladder, but very thin and not bitter in the Liver; so that from a Conjunction of the cystic and hepatic Bile a very powerful animal Soap is formed

(\$. 98, and 99.)

14 This Peculiarity of the Circulation feems not to have been sufficiently considered by any one. A Circumstance which put me upon framing a new Hypothesis, was the Inspection of the Body of an Officer in the Army, who had gone through all the Degrees of the yellow, green, and black Jaundice, accompanied also with a bilious Cachexy, and at length a Dropfy of the Abdomen and lower Extremities. Leave was with fome Difficulty obtained by the Physician, who had diligently attended the Disease, to examine into the State of the deceased Body. Upon opening the Abdomen, the Liver appeared scarce equal to a Hand's Breadth, and about the fame Thickness, but as tough as Leather itself, while the Spleen was twelve times as large as is usual in a healthy Body. I used my utmost Attention to enquire into the bottom of this Matter, and at last perceived that the Liver being obstructed, the Blood therefore stagnated, and was collected in the Veins which lead to the Sinus of the Porta, until at length vomiting and convulfive Motions occasioned the Blood to alter its Course, and to pass in a contrary Direction through the corresponding Arteries into the Aorta itself. Nor does this retrograde Course of the Blood seem improbable, if we confider that there are no Valves to refift its Return, except in the Vafa brevia: but in the mean time it is evident from Hydraulics, that if a greater Preffure or Reliftance be made upon the Liver than at the Extremities of the Arteries, the Blood will then return into the Arteries, instead of flowing towards the Liver. Upon defiring my Friend Ruysch to make the Experiment, he answered, that his Injection returned from the mesenteric Veins into

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to the Arteries; but that upon tying the mesenteric Veins at the Liver, Wind being inflated found a Passage through the Arteries into the Cava. One may easily conceive what miserable Disorders must arise from such a Perversion of the Blood's Course.

15 This Sinus has still a greater Resemblance to the Heart in a Fœtus, who whilst living in the Mothers Womb, receives all the Blood which is brought by the umbilical Veins into the Sinus of the Vena Portæ, from whence it passes by a short Course into the Cava and Heart. But in Adults all the Blood is not indeed derived into the Porta, but only that Part of it which has been fent through the Viscera of the Abdomen. In fact the Structure of the Sinus of the Vena Portæ is like that of the Heart: for it appears from the Observations of Malpighi, that the Heart which first appears in the Chick, is no more at the Beginning than a Vein variously inflected, round which a Muscle afterwards grows; but what else is the Sinus of the Vena Portæ than a Vein encompassed with a Muscle? The true Use of the Heart is to receive all the Blood from the Veins and propel it into the Arteries, that the feveral Secretions may be duly made from it in the feveral Parts where those Arteries terminate. But the same is the Action of the Sinus of the Vena Portæ in Adults, with refpect to the chylificative Organs. For to the Liver comes all the Blood of the Stomach, Intestines, Omentum and Spleen; and the fame Blood is propelled from the Sinus of the Vena Portæ into its arterial or converging Branches, distributed through the Liver, where the Bile is separated from this Blood. But the Parallel runs even further, for as the Heart has a subsidiary Organ of its own, to attenuate the Blood, namely, the Lungs; fo the Liver is provided with a Viscus destined to the same G 2

Office, namely, the Spleen. No Objection can be therefore made to our calling the Sinus of the Vena Portæ a kind of Heart in the Abdomen for the

Preparation of the Chyle.

16 Among a thousand Cures of acute Diseases, there is hardly one perfect Cure to be alledged, either of a Dropfy, Jaundice or splenetic Disorder; and even among a hundred chronical Difeases, there is hardly one whose principal Seat or Cause is not in the Liver. For the Medicines which are destined to open Obstructions of the Liver, are obliged to take a very long and round-about Courfe through the lacteal Vessels to the Heart, from thence through the small Arteries of the Intestines and other Viscera; and from these Arteries again into the mefenteric and other Veins leading to the Sinus of the Porta in the Liver: and therefore we cannot wonder that there are so few Medicines as yet found capable of retaining their Nature and Action through fo long and winding a Passage. Besides this we may add that the Powers of Nature, which form Crises in other Parts of the Body, do not in this Part afford any Affiltance to the Physician; for the Force of the Heart is no where more weak and distant, and the Blood has not here that Action of the Arteries by which its impervious Matter may be To attenuated as to pass off in a critical Discharge, as it fometimes does, for inflance, by spitting in a Pleurify; but the Humours being here thick or viscid and carried with a very slow Motion, are notwithstanding all Nature's Precautions to the contrary, much inclined to form incorrigible Ob-Atructions. The only Relief that can be expected in these Cases must result from the exciting of a flight Fever, at the fame time using diluent and attenuating Medicines, which being partly absorbed by the mesenteric Veins, a small Portion of them

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may pass immediately to the Liver, without first pervading the Heart. Of this Nature are the Whey of Milk, Decoctions of Grass-roots, purging Waters drank plentifully, &c. which if accompanied with riding in a Chair, are almost a specific Cure for Obstructions of the Liver. Hippocrates cured his hypochondriacal Patients only with Mead. Hence the Method of treating hypochondriacal Disorders with the Bark, is not so agreeable to Nature, inasmuch as it is an Astringent, and suppresses the slight Fever, by which only we can hope for a Resolution of the obstructing Matter in the Vessels of the Liver.

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17 The Ancients being ignorant of the lacteal Veffels, therefore supposed that the Chyle was drank up in the Intestines by the mesenteric Veins. and by them conveyed to the Liver; which Vifcus appearing above all others like Blood, changed the Chyle into that Humour, fince they could find none of the Chyle in the Vena Cava; therefore that the Chyle being converted into Blood in the Liver, was carried from thence by the Vena Cava to be distributed throughout the whole Body, the Liver being the common Origin of all the Veins. But, 1. The mesenteric Veins do not absorb the white and nutritious Parts of the Chyle, fince that milky Juice is conveyed by the Lacteals to a Part very distant from the Liver. And, 2. There is no Power in the Liver by which it can immediately convert the Chyle into Blood; infomuch that if Sanguification itself is destroyed, the Liver will be also spoiled, or at least afflicted a long time with chronical Diforders: whence it follows that the Liver is only a chylificative Organ, and that its Office is to prepare the Bile.

<sup>18</sup> The Spleen, Omentum, Mesentery, twofold arterial Action, and twofold venal Mixture, all

concur to prepare this one Liquor. The Semen has also a long Course for its Preparation, and passes through other smaller Arteries, where the seminal Arteries change into the Beginning of the spermatic Ducts; while other Vessels, like Arteries, form the convoluted Vessels of the Epididymis terminating in the Ductus Higmori. But this Analogy is something more remote from the Arteries.

19 The Chyle, as yet a foreign Juice, is fo vifcid when it first approaches the Mouths of the lacteal Veins, that it would not be capable of being abforbed, unless the Bile which there mixes with it, render'd it more fluid, dilute, and more nearly approaching the Nature of animal Juices. this Action of the Bile must be very considerable, to produce fuch Effects after it has been fo much diluted and discharged from its proper Receptacle. But that the Bile is the most exalted in Nature among the animal Juices, is demonstrated from its Causes, since it suffers more from the Action of the vital Powers, than any other Humour in the whole Body: for the Elaboration of all the Humours is reducible to the Action or contracting Force of the Solids, and the Mixture or Addition of other Juices, which are already of our own Na-The first of these Actions is communicated to the Humours in the Arteries, and the latter in the Veins: but the Bile has been twice arterial and twice venal, as we before demonstrated,

An Excrement is formething cast out of the healthy Body by the vital Powers, so that it never afterwards mixes again with the circulating Humours: but the Bile is not discharged out of the Body, since it mixes with one of the most useful Juices the Chyle, in the Formation of which it has so great an Efficacy, that the whole Business of

Chylifi-

Chylification ceases immediately, if the Bile is not mixed as usual. This was first demonstrated by Helmont, (as we observed in §. 102.) In the most voracious Animals and gluttonous Men, (fuch as was the Waterman or Gally-rower of Vefalius, (1.) the Bile pours itself either into the Pylorus, or into the Stomach itself. The Ancients had some Notion of this thing, fince they tell us that those who have a rifing of bitter Bile in their Throat are extremely hungry. (2.) But in most People, and in brute Animals, the Bile discharges itself into that Part of the Intestines, where the lacteal Vessels begin to arise. (3.) In the most voracious Fish, who digest their Food without Heat or Mastication, the Liver extends itself for a long way, together with the intestinal Tube, and the Bile is discharged in these Animals into the Intestines at a confiderable Diffance from the Stomach. But in no Animal is the Bile discharged into the Rectum. which yet would have been the most proper Receptacle, if the Bile was an Excrement.

Humour, but that the Liver prepares the same Humour for giving the Chyle such a Disposition, as may enable it to pass through all the small Vessels, and through the narrow Extremities of the pulmonary and other Arteries, without injuring the Health of the Animal. Milk and Chyle very easily turn to Curds and Whey; to prevent which, the Country People know how, namely, by adding of Sugar, Soap, Bile, &c. For when these are mixed, no Cheese can be made from the Milk. This then is the Use of the Bile with respect to the Chyle, namely, to render it a smooth, uniform Juice, and prevent its Parts from separating or curdling, so as to be afterwards impervious in the

Veffels.

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## Of the Action of the KIDNEYS.

§. 351. HAVING already treated sufficiently concerning the Pancreas, Mesentery, Stomach, Intestines, &c. subservient to Chylification, the Order of the Parts requires of us next to explain the Action of the Kidneys.

§. 352. The Kidneys 1 are so situated and connected, that the Motions 2 of the adjacent Parts promote the Secretion and Excretion of the Urine, and this more especially in the right Kidney; but both of them are defended under 3 the Membrane of the Peritonæum, and by the hard Fat 4 with which they are invested, They receive Glands fasten'd at their top, inclined a little towards their Excavation, which is almost constantly 5 the Situation of these Glands; though fometimes being removed from the Surface of the Kidneys, they adhere firmly to the Diaphragm, being hardly ever of the same Form in two different People, nor of the same Magnitude; but they are depressed, or of a flat Figure like a little Placenta, and furnished with Arteries and Veins, varying in their Origin and Distribution. The Kidneys are next furnished from the descending Aorta, each with a confiderable 6 Branch,

or fometimes with more Branches than one; from which Arteries the Kidneys again receive another Tunic, and dividing themselves into four, five, or more Branches, and these again into much smaller Arteries, they at last disappear in very thin Circles or Arches distributed throughout the whole Substance of the Kidneys. These last Branches of the Arteries running in a vermicular Course, mutually uniting with each other, and separating again, seem to constitute, as it were, Heaps 7 or Glands: But from the Extremities of these Arteries the reductory small Veins seem to arise, which gradually unite 8 into larger, terminating at length in four or five confiderable Branches, which end in one or more Veins called the Emulgents; and at the same time lateral Ducts also arise from those Extremities of the Arteries, which being almost pellucid, receive and convey the Urine separated from the small Arteriolæ; and uniting together, they form many pyramidal Bodies, having several Angles, which at length terminate usually in twelve membranous Bodies called Papillæ 9, into which many of the renal Tubes collected together open obliquely on all Sides, as well from within as without.

All fanguineous Animals are found to be furnished with Kidneys. And although there are some who imagine that Birds are destitute of Kidneys, because they have no Urethra; yet it is certain that all feathered Animals have Kidneys, and separate as well as discharge Urine: But then in Fowls

Fowls there is no particular Passage for the Discharge of the Urine; but the Ureters are inserted into the Anus, which the Ancients properly enough denominated Uropygium (ex urina & natibus); so that the Urine is evacuated in seathered Animals together with the intestinal Fæces. Hence it is that many Animals of the Bird-kind discharge their Fæces in a fluid Form, as we frequently see in Hens; but when they sit upon their Eggs, they do not discharge the drier Fæces for a considerable time, until they have been first softened by the affluent Urine. The Dung of Storks is white and fluid.

<sup>2</sup> I have frequently observed in opening living Dogs, that the Kidneys descend at the time of Infpiration, and rife up again at the time of Expira-And in living Animals who are not opened, they readily receive a Pressure from the circumjacent Parts, though not fo confiderable as the Spleen. Besides this, they also receive a considerable Motion from the Muscles of the Loins upon which they are incumbent, infomuch that Stones are feldom formed in the Kidneys, except in those who have a long time neglected the proper Exer-All the Causes which we have becifes of Body. fore enumerated, were necessary to move the Kidneys to forward the Urine from the Pelvis into the Ureter, that is, from a larger to a smaller Canal; and therefore when these Motions are not communicated for want of the Exercise of Body, the Urine stagnates and forms Calculi. It is also remarkable, that Brutes do not make Water freely after the Abdomen has been opened. But the right Kidney is moved more than the left, which is generally a little higher than the right; and therefore Calculi are more feldom found in the right than in the left Kidney. Add to this, that the Stomach being diftended,

ed, may also compress the left Kidney, so that it cannot be moved to evacuate its Contents, which in this Viscus is not promoted by any muscular Force

of their own.

3 The Kidneys are not truly contained in the Cavity of the Abdomen, nor are the emulgent Arteries or Veins together with the Aorta and Vena Cava; for all these are only covered before by the Peritonaum, as they are incumbent on the Loins. So that the Blood which is at any time extravafated from the Kidneys, does not flow into the Cavity of the Abdomen, as some have imagined, but betwixt the Loins and the Peritonæum into the cellular membrane. Even if the Kidneys are suppurated, an Empyema of the Abdomen does not thence follow, but the Loins only fuffer: infomuch that fometimes a very large Abfcefs shews itself in the Back, which sometimes breaking either spontaneously, or by the Assistance of a Surgeon, there is a ready Passage for a Catheter to pass into the Pelvis of the Kidney itself, in such a manner, that the Urine has been fometimes difcharged through the Back by a grooved Probe or Director. Nephrotomy, or an Incision has been made upon the Kidney through the Back in some Cases; and this bold Operation was performed by Marchetti upon the English Ambassador.

4 The Kidneys are lined with Fat only on their external Surface, but have not the least Fat on the Infide; from whence we have a Saying, that the Kidneys, like covetous Men, are lean in the midft of Fatness. The Kidney seems to be thus invested with Fat, to qualify the Acrimony and putrid Quality of the Urine, as well as to obtund the alcaline Salts, that they might not prey upon the Fabric of the Gland itself, as Malpighi well obferves. But this foft Fat gives way to the Kidney.

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whenever it is distended by too violent Motion of the Blood. But this Fat is naturally of a drier and harder Consistence than that in other Parts of the Body; and therefore when it abounds in too great a Quantity, it may so compress the Kidney, as to retain the gross Parts of the Urine, while the more sluid are discharged, whence a Calculus may sollow. And if in opening a dead Body there appears much Fat upon the Kidneys, one may be affured that the Person was inclined to the Gravel.

\* Eustachius was the Discoverer of these Glands. the various Conditions of which he has well expressed in his Tables, in the manner as they most frequently appear upon the Kidneys, infomuch that they are scarce alike in the Kidneys of two different People; but yet he has never omitted these Glands, only placed them sometimes nearer, and fometimes at a greater Distance from the Kidneys, varying both their Figure and Situation. The Constancy of Nature in supplying the Kidneys always with these Glands, seems to argue that they have some Use towards the regular Secretion of the Urine; and perhaps they may be to separate a kind of Liquor, or prepare the Blood, as in the Spleen, which by mixing with the venal Blood of the Emulgents, may supply that Defect of Fluidity, which arises in it from the Separation of its watery Parts. They very strictly cohere with the Diaphragm, in such a manner that they can hardly ever be at rest; and therefore we never find any stony Concretions in these Glands. They have Arteries and Veins peculiar to themselves.

6 Large enough to receive one's Finger; infomuch that hardly any other Viscus has Arteries so large. And from this Largeness of the renal Arteries we may judge of the vast Quantity of Hu-

mours,

mours, which perpetually circulate in a given time through this no fuch very large Viscus. These Arteries immediately deposit their external Tunic, as in the Brain, as foon as they enter the Kidney. which ferves to compose the external Tunic of the Viscus.

7 The Artery which goes to the Kidney immediately divides itself into many Branches, which have a different Appearance in their Disposition from those in any other Part of the Body. For all the Arteries are extended to the convex Surface of the Kidney, where their small Extremities are inflected in and out in a serpentine Course. Through these serpentine Branches neither Lymph, Milk, nor Chyle are fuffer'd to pass into the uriniferous Ducts, at least in a healthy State, nor is there any Part of the Body in which fo large Arteries fo fuddenly diminish into the smallest Branches; for the Arteriolæ, which arise from the larger Circles or Arches, are not at all thicker than a Hair of one's Head.

<sup>6</sup> For many Ducts, perhaps a thousand, lie close to each other, and open their Extremities through the whole Surface of each Papilla, which discharge the Urine through open Pores into the Pelvis. But that the Urine might not return out of the Pelvis into the Papillæ, they are each of them armed with a kind of Membrane or Valve, which fecludes the Mouths of the Ducts for as to permit the Urine to flow into the Pelvis, but prevent its Return. Through these Orifices the ceraceous Injection of Ruysch being artfully impelled, makes its way even into the Pelvis of the Kidney from These Tubuli or Ducts, which bear the Arteries. the Name of Bellini, were fo called from his difcovering them before the Tables of Eustachius were found.

found, in which they had been represented above

one hundred and thirty Years before.

9 Namely, every particular Branch goes to a particular Part of each Kidney, almost in the manner of a diffinct Gland, as well in the human Body as in other brute Animals, though it is usually represented otherwise. Eustachius has demonstrated this conglomerate Structure of the Kidneys in the Bear and Tortoife; for in these Animals the Kidneys appear composed of an Assemblage of many angled Glands, separated from each other; each of which have an Artery and Vein, with a diffinct Pelvis: all which Pelves meet together in one. In the Hedgehog the Kidney is composed, as it were, of a Heap of Glands like a Bunch of Grapes; and in the human Fœtus the Kidneys are divided into distinct Portions by the Fat; but afterwards these Portions unite into one larger Kidney, as hath been demonstrated by Eustachius, and fince confirmed by Ruysch; fo that in adult People the Portions, which were before distinct, unite into one uniform Body, whereas in Oxen they remain distinct as long as the Animal lives. But though the distinct Portions thus unite into one uniform Body, yet there remains some of the Footsteps of their Divisions; and there are as many diffinct Papillæ, or pyramidal Bodies, as the Kidney was before divided into distinct Portions, usually about twelve. the Cause of this Alteration seems to be the Pressure of the Arteries, compacting the dividing Portions together. Suppose twelve hollow Balls of Wax were to be affembled together, with each a distinct Tube or Stalk, they might by any external Force be urged together into one continued Mass; but then the Bodies which were before globular will become hexagonal, and touch each other in plain Surfaces; but internally their Ducts will terminate

in a Point, so as to form a pyramidal Body, like unto those which are called the Corpora Pyramidalia by Malpighi and Bellini; and thus the several Portions will be combined into one Kidney, tho each of them remain capable of performing their distinct Office. But the Figure of these pyramidal Bodies results from a Combination of the Artery, Vein and Duct in the broader Basis, at length terminating only in a single Point, or a solitary uriniferous Duct, forming the smaller Part of the Pyramid.

§. 353. In the Substance of the Kidneys there are also found small, round, hollow Bodies 1, invested on all Sides with the smallest Vessels 2, furnished with small Veins and Nerves, as well as with the smallest Arteries, and are continued even to the uriniferous Tubes: all which is confirmed by stony Concretions and other Disorders 3 of the Kidneys, as also the Appearance of them in Hedgehogs, Tortoises, and in the human Fœtus. Hence therefore the Urine feems to be feparated two ways in the Kidney, namely, by a glandular Apparatus 4, and by the more fimple vascular Apparatus of Ruysch 5; and this is also conformable to the Course of Nature in other Parts, as, for Instance, in the Liver: But this last Apparatus Ruysch imagines, upon the strictest Enquiry, not to be Glands, but only Contortions, or Twirles of the smallest Arteries.

Ruysch allows that there are certain Bodies which have the Appearance of Glands, concerning

ing which he has often changed his Opinion about them; but at length he determined, from the gigantic or tall Woman whom he diffected, that they were refolvable into real and continuous fmall Veffels, being nothing more than the Extremities of the Arteries. And to prove this, he urges a very cogent Argument, namely, that Liquors pass directly from the Arteries into the urinary Pelvis, without forming any Knots or Diffentions, which would certainly appear, if there was any intermediate Receptacle betwixt the Extremity of the Artery, and the Beginning of the uriniferous Duct. But this Experiment does not prove that there are no Glands: for the larger Veffels might fo conceal by their Diffention the intermediate Follicles, as totally to obscure them in his Preparations.

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Malpighi injected Urine mixed with Ink into the renal Arteries, which filled the smallest Arteries dispersed in this glandular Apparatus, and all their Follicles were likewise distended with the

fame Liquor.

3 In the Body of a Woman diffected by Malpighi, the Kidney was found full of spherical stony Corpuscles, which discharged stony Threads into the Pelvis, which was also full of Calculi.

\* By which glandular Fabric, a small Quantity of Urine seems to be separated of a more acrid and gross Nature than that distilled from the Vessels, which is more watery and tinged or coloured by the other: And that Nature sometimes uses a two-fold Apparatus for the Separation of a Humour, is evident, for Instance, in the Testicle.

By this simple or direct Course the Urine is immediately and continually distilled, at least a greater Part of it, which appears thin, watery, and colourless: nor is there any other Way by which such large Quantities of Urine are so speedily evacuated after much drinking.

§. 354.

§. 354. But there is still another Part of the renal Artery, whose Office is to support the Warmth, and administer the nutritious Matter necessary for continuing the Life of the Substance of the Kidney itself; and it is from the Blood of this Artery, that the Lymph feems to be feparated, which is fo plentifully returned from the Kidney to the Receptacle of the Chyle, to be returned into the common Circulation; which Lymph is healthy or found, and not excrementitious, nor has it any Taste of the Urine. From these Arteries also there are doubtless peculiar Veins, which arise corresponding to them, to return the superfluous Blood.

· Namely, the Lymph which is redundant over and above what was conveyed by the lymphatic Arteries for the Nutrition of the Parts; which entring pellucid Veins, passes towards the Heart, without having any Communication with the watery Parts of the Urine. It is indeed commonly supposed that the Kidneys purge the Lymph; but the watery Part of the Urine is very different from the ferous or lymphatic Part of the Blood, which are of a fweet and gelatinous Nature, concreting with the Heat of boiling Water like unto the White of an Egg (§. 123.); whereas the Urine is a Lixivium, volatile, and very acrid (§. 380.)

§. 355. For the smallest Veins arising from the ultimate Extremities of the renal Arteries (§. 452.) meeting together form larger Veins, whose Branches divide and meet in the fame H manner

Action of the Kidneys.

manner with the Arteries; and at length terminating in an uncertain Number of Trunks. they discharge the Blood remaining after the Secretion into some Part of the Vena Cava.

As for the Blood which returns from the renal Glands, that is discharged into the emulgent Veins and Cava; which was necessary, as the Blood of the Kidney has been in a great measure deprived of its diluting watery Parts; for of eight Pounds of Aliment, near two are discharged by Urine: and therefore the Blood of the emulgent Veins must be very thick, and stand in need of some Means for its Dilution.

§. 356. Now the renal Papillæ (§. 352.) distil the Urine 1 brought by the uriniferous Ducts into a large membranous Cavity called the Pelvis, furnished with a soft Fat of its own; in which Cavity being collected, retarded 2, and mixed, it is drove from the Pelvis into a narrower Duct called the Ureter, by which the Urine is at length conveyed into the Bladder.

If warm Water be injected into the emulgent Artery, Part of that Water will enter into the Veins, and return to the Cava; and another Part of the same Water will distil through the uriniferous Ducts and Papillæ into the Pelvis and Ureter. But if the Kidney be first well washed clean by injecting Water, and after filling the Arteries with a fluid ceraceous Injection, you then expose the whole Kidney to macerate or putrify, the Tubuli Belliniani will then be found turgid with the Injection, and you will have an Opportunity of fee-

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ing that every Point of the Papillæ detaches a little Cylinder of Wax into the Pelvis, in the fame manner as the Urine was conveyed before. These Tubuli therefore arise from the lateral Extremities of the smallest Arteries, and distill the Urine which they receive into the common Receptacle.

This Slowness of the Passage of the Urine occasions the frequent Formation of Calculi in the Ureter; nor could this Inconvenience be avoided, since such a Receptacle was necessary to be made, as might forward the Motion of the Urine through the Ureters, and in a manner relax the Papillaelike a continual Bath, lest if they should be dried up, they might become impervious.

§. 357. Now there are eleven i or twelve membranous Canals, which arise from the Circumference of the Papillæ (§. 356.) which they embrace, and receive the Urine which distils from them; and at length passing into three large Branches, they unite and form one large Pelvis; which Pelvis 2 terminates in a fingle, thick and strong membranous Canal, replenished with Arteries 3, Veins, Nerves, and lymphatic Veffels; also furnished with muscular Fibres and mucous Duets 4 for lubricating the Sides. This Duct, which is called the Ureter, descends first directly downward, but is soon after inflected 5 a little in its Course, which is always under 6 the Lamella of the Peritonæum, being of an unequal 7 Diameter in different Parts, till at length it is inferted towards the Back and lower Part of the Bladder, at about the Distance of two Fingers H 2 Breadth

Breadth from its Neck, and as far from each other: but they here enter the Bladder by paffing first through its external Coat, and running for about the Length of a small Finger's Breadth obliquely betwixt that and the interior Coat; it then enters the Cavity of the Bladder by thrusting out its round 8 protuberant Fibres, which being continued downward, form a cylindrical or round Body of some Length, by which the Urine is prevented from flowing back into the Ureter when the Bladder is full; at which time its Coats being expanded, the opening is closed, and a free Passage allowed to the Urine to enter into the Bladder 9, while the cylindrical Body and oblique Infertion of the Ureter prevent any thing from returning out of the Bladder, even though it be attempted by a confiderable Pressure.

The common Number is twelve, though there are sometimes only six or eight, as Eustachius represents in some of the Figures of his Tables; but this is seldom observed. The same Anatomist has given an excellent Figure, where, contrary to the common Course of Nature, there are twelve distinct Branches: for the Pelvis usually divides itself either into two or three Trunks; if three, each Trunk corresponds to sour Papillæ; but if there are sour Branches, then each Branch terminates in three Papillæ.

There are distinct Membranes which embrace each of the Papillæ, which Membranes being collected into one large Sinus form the Pelvis. About the Pelvis there is disposed a large Quantity of Fat to facilitate the Motion of its Contents; for

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when that Fat is confumed, which naturally is abforbed and conveyed into the Cavities of the Kidney, it occasions severe Pains and other Disorders.

<sup>3</sup> Hence therefore the Ureter may fuffer all those Disorders, which are capable of invading any other vascular or membranous Part of the Body; namely, Inflammations, Suppurations, Scirrhofities, &c. A Knowledge of which is necessary, in order for us to discover the Causes of Diseases in these Parts. From Inflammation follows a Stricture of the Ureter, which causes an Ischuria or Suppression of Urine without any Fault in the Bladder. There was an English Minister at Amsterdam, who every Month was afflicted with this Disorder, which gave way to the same Treatment which is necessary for all other Inflammations of the Body, namely, Phlebotomy.

4 These mucous Drains are seated in the cellular Membrane, from whence that Oil comes which is often discharged in the Urine after violent Exercifes of Body: which Contrivance was necessary. that the fenfible Membranes of the Ureter, lubricated by the oily Mucus, might not be corroded or excited to Pain by the Acrimony of the Urine.

From this Inflection of the Ureter it is, that the Pain arifing from the Gravel is first perceived in the Loins, then in the Sides, and gradually more inward, till at length it is severe under the Pubes; then vanishes for a time, and afterwards produces a Strangury. Namely, the first Pain is in the Kidney, the next in each of the Inflections of the Ureter, till the Calculus has slipped into the Bladder, and then the Pain ceases.

Where the Peritonæum recedes from the Loins. and covers the Bladder, there the Ureter descends into this large Pelvis, constantly terminating in the lower lateral and posterior Part of its Neck.

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Where-ever the Ureter becomes of a less Diameter, there the Stone will frequently hesitate and distend the Canal to the Thickness of an Egg, of which we have an Instance given us by Nucke.

<sup>8</sup> Here the muscular Fibres become thicker than in other Parts of the Bladder, as Eustachius has long ago represented, and as De Graaf has well described, inclining towards the Neck of the Blad-These being contracted whenever the Bladder is distended with a large Quantity of Urine, close up the Mouth of the Ureter, and prevent any of the Urine from returning; and this they do more powerfully, as the Bladder is more diftended. For there is not any Valve at the Entrance of the Ureter, as hath been formerly imagined; but the simple Mechanism here described answers that Intention, fince there is always a greater Column preffing upon the oblique Canal towards the Bladder, and but a small Pressure from the Bladder; and therefore the Urine is eafily excluded from returning into the Ureter.

The Urine now enters a large Receptacle, and this with confiderable Advantage to the human Species, who being defigned for a fociable Life and various Employments, as well as to study and Meditation, thus avoid the Detriment which would have ensued from a perpetual Discharge of this Excrement. But then with this Advantage there follows great Danger of breeding the Stone, since the Urine cannot stagnate long in any Part, without giving an Opportunity to some of its grossest Particles to be deposited, which may lay the Basis of a future Stone.

§. 358. The Truth of all this Doctrine is demonstrated by the Microscope, Injections 1, Liga-

Ligatures 2, the comparative Anatomy of these Parts in Hedgehogs 3, Dormice, Tortoifes, Bears, Oxen, Birds, and human Fœtus's; as also the Dissection of human Bodies, who have been obnoxious to Diseases of the Kidneys, or to monstrous and preternatural Dispositions of them.

Ink, which Liquor, as also the melted ceraceous Injection, we at present know by Experiment will return from the Artery through the renal Vein, and also into the Ureter. If the emulgent Vein be first tied, and the Kidney so adapted in an exhausted Receiver, that only its Artery can communicate with the Atmosphere, the Pressure of the Air will then force Water through the immerged Artery into the Ureter, and by that into the exhausted Receiver. Drelincourt having tied the Pelvis, blowed Air into the Arteries, which penetrated into the uriniferous Ducts.

\* If a Ligature be made upon the Ureter in a living Animal, nothing will pass into the Bladder, but that Part of the Ureter betwixt the Kidney and the Ligature will be wonderfully distended; or if you tie the emulgent Artery, there will be al-

fo no Urine discharged.

3 I include the Hedgehog of both Kinds, as well the Indian called the Porcupine, as the European, which Animals have a kind of Thorns and Spikes instead of Hair; but even the Kidneys appear still more evidently composed of an Assemblage of distinct Glands than in these Animals, if we examine into the Tortoise.

§. 359. Hence we understand that the Separation of the Urine is mechanically per-H 4 formed

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formed by the Force 1 of the adjacent Heart and strong Arteries, by which the watery Blood is urged through the innumerable Turnings and Windings of the Vessels, by whose Resistance 2, opposite Motions and Concussions, an intimate Mixture is first made, and at length the more aqueous 3 and excrementatious Parts are separated, propelled forward, collected and discharged through Ducts a little smaller than the Blood-vessels themselves.

To this add the Force of Respiration, which promotes the Secretion of the Urine by a continu-

al Succussion of the Parts.

The many Turnings, Windings or Arches and ferpentine Courses of the smallest Arteries, and the Assemblage of them into Heaps, was not so produced but for some End, namely, to prevent the Passage of those Juices which ought not to enter the uriniferous Tubes. And from hence it is, with the Compactness of the Kidney, that only the Urine is permitted to flow through the secretory Ducts, while the Blood, Serum, Milk, &c. are retained. But sometimes we see that all of them pass the same way, as in a true Diabetes, but then there is a morbid Relaxation of the renal Ducts.

The Blood of the renal Arteries carries all the Humours mix'd together, both Lymph, Chyle, the absorbed Vapours, and all the more subtle Humours, without depositing any Part; and it is therefore replenished with the Matter of Urine which consists of watery Juices, which Juices are more sluid than either the Blood itself, its Serum or Milk; insomuch that if there are any Humours more sluid than those which compose the Urine, they must be quite invisible.

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§. 360. There is not therefore any Occasion to account for this Secretion by supposing any attractive 1, emulfive 2, or the like Faculties in the Kidneys.

In short, the Nature of this Secretion confists entirely in an expulsive Force; nor does Attraction ever duly separate those Parts which are excrementitious from the arterial Blood, and leave behind the Parts of the Humours which are useful and necessary for the Preservation of the human Body.

<sup>2</sup> From this Faculty, which the Ancients suppofed to refide in the Kidneys, they denominated their Arteries and Veins Emulgents, as if the Urine was formed by milking or pressing out that Humour from the Blood through the Branches of the Papillæ: But all these imaginary Faculties are only a Cloak for Ignorance.

- §. 361. Nor is there any Occasion to invoke an urinous Ferment 1, fince there is neither Place 2, Cause, Time 3, Matter 4, nor any Effects or Mixture of any fuch Ferment to be demonstrated for making the Urine.
- Several Authors have supposed the Urine to be a Liquor of a particular Nature, which did not before exist in the Body, but is generated in the Kidneys, and discharged from the Bladder. They likewise add, that the Seat of this Ferment is in the Kidneys, and therefore the Kidneys always tafte of Urine after they have been boiled. But we are well affured that the Urine, which confifts of the watery, acrid, and excrementitious Parts of the Blood and Hymours, existed and circulated in the Blood

Blood long before it was from thence separated. The Secretion of the Urine is therefore performed by a simple Apparatus assisted by the Impulse of the Heart and Arteries; for if a Liquor be injected into the Arteries, barely the Pressure of the Syringe will force it through the secretory Ducts into the Ureter, without making any considerable Alteration in it.

2 Such a Ferment cannot refide in the Arteries, fince no Humour refides in them for any time, and the Blood continually passes through with a swift Motion: for in the Arteries the Blood as yet looks red, but in the Tubuli of Bellini it is become U-Nor can any fuch Ferment be feated in the Veins which return their Blood to the Heart, nor yet in the large Pelvis of the Kidney, fince in that the Urine is already perfectly separated: nor yet can a Ferment lodge in the glandular Bodies of Malpighi, which are but few; and more especially fince the greater Part of the Urine is distilled immediately from the Arteries, which are directly continued to the Veins. In short, the Urine is continually poured from the Arteries into the Ureters, and by them conveyed into the Bladder, as any one may be convinced by an eafy Experiment: for if all the Urine be evacuated from the Bladder, after a short Interval one may discharge a few Drops more, which were separated from the Blood in that short time.

There is not any Ferment known, which operates immediately upon its Mixture without requiring some time to alter the Liquor with which it is mixed; but we have already observed, that the Blood does not make any Stay in the Kidneys, but, on the contrary, the Celerity of the arterial Blood in passing through the Kidneys, is confirmed by the constant and speedy Discharge of watery Li-

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quors by Urine foon after they have been drank. Do but confider how many Pounds of mineral Waters are often drank for a Breakfast, and which are all again evacuated by Urine in about a couple of Hours time.

\* No Ferment can be formed of the arterial Blood; for if it was contained in that, all the Vifcera would eafily partake thereof. Nor can it be formed in the Kidney, which is so compact a Vifcus; notwithstanding Helmont afferts, that there is a peculiar rank Taste in the Kidneys after they have been boiled: for that disagreeable Smell and Taste lies in the Pelvis, and is there derived from the Urine altered by the Heat of the Body. Even if a Ferment was to be granted in the Kidneys, it could never be sufficient to tinge the vast Quantity of Urine, which passes through the Kidneys during the Life of Man.

§. 362. And for the same Reasons (§. 361.) we ought neither to have recourse to any fufing or precipitating 1 Virtue.

The Chemists not content with the simple Fabric of the Parts, must have the Secretion of the Urine accounted for by some Operation better known to themselves than to the Nature of the Animal: and therefore they suppose every animal Juice to be derived from another which is more gross, and this in the manner of Precipitation, as when an Acid separates the curdled Parts from the Serum of the Milk. They therefore suppose the Mixture of some certain Liquor with the Blood of the Kidneys, which causes a Separation of the more subtle from the more gross Parts, namely, a Separation of the Urine from the more thick Blood. Dr. Willis goes farther, and illustrates his Opinion

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by an Example of medicated Salts, by whose Efficacy large Quantities of Urine are derived from the Kidneys. But to what purpose is it for us to lose our time in searching into obscure and precarious Notions, when the Fabric of the Parts are sufficient to account for all the Appearances? Besides this, what has been said (§. 256.) concerning Ferments, will be of equal Force against Precipitations.

§. 363. It is also from hence evident, that what Helmont 1 has seigned so industriously with regard to liquid Dung or Scoria mixed in the Kidneys as a Preservative against the Stone, must also sall to the Ground together with the preceding Hypothesis.

Helmont, who was a Man of some Ingenuity, gives us his Opinion in a Treatife of the Stone, that he believed the Urine to be formed in the Kidneys of a Humour which was not before Urine, by the Mixture of a liquid Dung, which was derived from the adjacent Intestinum coecum. And he there goes on in the following Method of reafoning: That all the Urine of a calculous Patient is thin and clear, even though all the other Parts of his Body are in Health; and that therefore when the Urine is yellow, no Calculus is generated: but if by a chemical Analysis you enquire into the Nature of the stony Matter which tinges the Urine of a yellow Colour, it will be found feetid, and very much like the intestinal Fæces. fore, as the Fæces of the Intestines are putrified by fomething lodged in the Cœcum, fo the fœtid Matter of the Urine is conveyed from the same Fountain in the Cœcum into the Kidneys. this this liquid Dung from the Cœcum is a Preservative against the Stone, and therefore it ought to be rather increased or promoted than evacuated by the Physician. He then instances his Offa, which is a folid Body produced of two Liquors instantly upon Contact, namely, Spirit of Urine and Alcohol of Wine: and thus he imagines the Stone to be formed of Earth joined with a volatile urinous Spirit, which also volatilizes the Earth; but this liquid Dung was an Antidote to this Formation of the Stone. But this Doctrine needs no Argument to overthrow it, nor to demonstrate its Folly and Precariousness; nor is there any Duct in the human Body, whereby any fuch liquid Dung can be conveyed from the Intestinum cœcum to the Kidneys.

§. 364. And it is also very evident, that all the Humours which are thinner 1 than the Urine, will readily pass out this way through the uriniferous Ducts, if they are brought thither by the renal Arteries. From hence therefore we understand, that there must be fome Cause which prevents them from flowing hither (§. 223, 224.); or if they are brought to these Ducts, great Weakness 2 must foon follow. Now the Glands which are called Renes succenturiati, are always 3 lodged upon the upper Part of each Kidney, but distinctly separated from thence by the intervening Fat; and as they lie contiguous to the Diaphragm, they are in some measure attached to it by the Blood-veffels, which they from thence receive; and they are compressed betwixt that Muscle and the Kidneys, being furnished

furnished with Arteries, and without any proper excretory Ducts of their own, they appear of the like Structure with the Spleen 4, and to be subject to the like Actions with the Spleen. pouring almost all their Blood constantly thro' their Veins into the Emulgents, they feem to perform formething upon the venal Blood, which has been deprived of its more fluid, watery, and faline Parts by the Separation of the Urine, so that they seem to contribute to the venal Blood of the Kidneys, the same which the Spleen does by mixing its Blood with that of the Vena Portæ; but possibly there may be some other Use of those Glands. and yet that which is here affigned feems not unreasonable, till we acquire more Light into this Matter. But if the new Observation of Valsalva 5 was true with respect to these Glands, it would follow that we must alter our Opinion, and suppose them formed as affifting Organs to the Testicles for the Separation of the Semen.

That the Humour which passes through the Kidneys is extremely thin, is evident from the Compactness of that Viscus, which is much firmer than that of any of the other Viscera in the Body: Besides which, it is evident from the Inspection of the uriniferous Ducts, which can scarcely be perceived by the Eye, unless armed with a Microscope. It is therefore from hence easy to understand, that no Humour can pass though the Kidneys which is thicker than the Urine; but the Reason is more obscure, why the thinner Humours are not discharged by these Ducts, especially the Spirits.

Spirits, unless it is because the more compact and heavy Parts of the Blood are, by the Laws of Hydraulics carried downward, while the more light and spirituous Parts ascend into the superior Branches of the Aorta: and from that Law of Hydraulics by which the most folid Particles moving among others which are lefs folid, will continue on more in a right Line according to the Direction of their Motion; but that Direction in a straight Line is from the Heart towards the Head, and therefore the Blood which descends towards the Kidneys ought to be less folid, and composed of less moveable Particles; but so often as the Spirits and more fubtle Juices are drove to the Mouths of the uriniferous Tubes, there is no doubt but they will pass through into the Pelvis and Ureter.

<sup>2</sup> A Diabetes is a more frequent and copious Discharge of a watery or pale-colour'd Urine than is usual in a healthy State; the Urine appearing not falt but fweet, white and thick, as if charged with a great Part of the Chyle. This Diforder is the Confequence of a Laxity in the uriniferous Ducts, which is a very useful Circumstance for preventing the Gravel; but then by endeavouring to avoid the Gravel by perpetually drinking large Quantities of diuretic and diluent Liquors, the most useful and nutritious Parts of the Humours are washed away, and an Atrophe and Death itself are at length brought on. There are other Patients who are also subject to plentiful Discharges of a watery Urine from a different Cause, namely, in hysteric and hypochondriacal Disorders; but these last copious Discharges of Urine do not come under the Denomination of a Diabetes. But these Patients certainly discharge their Spirits together with the Urine which appears so watery, and therefore in England it is properly denominated a Lowness

Lowness of Spirits. And this happens to hypochondriacal People, who vex themselves in the Night with troublesome Thoughts, or throw themselves into a Rage with sudden Anger; but so soon as the Urine begins to look yellow, they always find themselves better.

Eustachius has given us many Figures of the Kidneys which appear so very different, that no two of them are in all respects alike; but yet he has never omitted the Glandulæ Succenturiatæ connected to the Diaphragm, and continually agitated

by its Motions.

• For like the Spleen they appear of a black Colour, of a spongy cellular Fabric, being also destitute of any excretory Duct, unless the Vein performs that Office. But their Use is also the same of that with the Spleen, if what many have fufpected be true, namely, that the Blood is poured out into the cellular Fabric of these Glands, and after suffering the Action of Respiration or Pressure of the Diaphragm, passes immediately into the Vena Cava or into the adjacent Vena Azygos without making any Secretion, and this in order to attenuate the venal Blood: at least it is certain that the Blood returning from the Kidney stands much in need of some such Assistance, since it has been deprived of its more fluid and moveable Particles, and is therefore more thick and fluggish.

This Anatomist perceiving Death approach called a Notary with Witnesses, together with several Physicians, and other learned Men, before whom he consigned over his Commentaries, describing a Duct which descended from these Glands to the seminal Vesicles. These posthumous Observations with other Experiments of Valsalva were afterwards made public by Morgagni as he acquainted me by a Letter in the Year 1720. Whatever

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there may be in this Observation, it is no difficult Matter to determine by Experiment, if the Vena Cava be tied above at the Heart, and below at the iliac Vessels, and then by exquisitely filling the emulgent Arteries with some coloured Injection. and making a strict Scrutiny whether any Duct remains after this Administration. But we have not been fince able by this or any other Artifice, to difcover any other Duct leading from these Glands, besides a small Nerve or an Artery, which descend parallel to the Spermatics from these Glands down to the Epididymis: and we know that in all Animals the spermatic Vessels arise near the Kidneys and atrabiliary Capfules in both Sexes; and from hence arose the Asiatic Phrase, for Children to come from the Loins of their Parents, Heb. vii. 10.

§. 365. It is also from hence evident, that the Urine never ceases to be secerned from the Blood, but continually flowing through the Kidneys, is one of the principal Causes of the Secretion itself; also preventing the Ureters from collapsing, being obstructed, compressed or concreting together, by which many other Disorders of the Kidneys are avoided.

This Disorder may easily happen in the Tubes of Bellini, which are extremely narrow, and placed without the Power of the circulating Blood, as also in the Ureters and Pelvis from the Glue with which they are perpetually lined; therefore to prevent them from collapsing or concreting by being stuffed up with Matter, Nature has caused the Urine to be perpetually distilling through them. Drelincourt having sastened a Bottle to the Ureter of a living Dog, observed that Drops of Urine I continually

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continually distilled into the Vessel. But to prevent a continual Flux which would be fo highly detrimental to the Animal, Nature has furnished a larger Receptacle, in which the Urine stagnating and parting with its more aqueous and fluid Humour, acquires a greater Disposition to breed the Stone, as well in the Kidneys as in the Bladder, when Exercise of Body is neglected. Hence fat People are frequently troubled with the Stone. In the Overfeer of the new Church of Leyden who was a very fat Man, one of the Kidneys was filled with a continued Mass of Stone as large as the Kidney itself, while the Viscera were buried in Fat. The Urine indeed contains in itself not only the Matter of a Calculus, but even the Urine of the most healthy Person is discharged full of true Calculi swimming in it, as I have frequently feen by viewing in a capillary Tube by the Microscope, and I have often made artificial Calculi of the fabulous Particles floating in it. In fhort, the true preservative Remedy against the Stone is not to be fought for among the Arcana of the Chemists but is to be expected only from Exercise with plentiful drinking of thin Liquors. If a Person who knows himfelf liable to the Gravel exercises moderately before Breakfast after drinking a Draught or two of pure Water, it will go a great way towards preventing the incipient Diforder. But nothing injures the Kidneys more than the Abuse of warm watery Liquors drank too plentifully or too hot and joined with Idleness or a sedentary Life; for thus is produced a Laxity of the renal Arteries, which gives the Blood an Opportunity to mistake its Course; and when once any of the red Parts of the Blood have enter'd the uriniferous Tubuli, they lay a fure Basis for a Calculus. Thus Fernelius has long ago observed, that there is a red Nucleus § 366. Action of the Bladder. 115

Nucleus always found in the middle of urinous Calculi; and Helmont wifely observes, that a Firmness or compact Texture of the Kidneys, is one of the safest Preservatives against the Stone.

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Of the Structure and Action of the Urinary Bladder.

§. 366. HE urinary Bladder is feated in the Pelvis under the Lamella of the Peritonæum; which is expanded above it, and being securely defended 1 by the several Bones, it appears to be made up of three distinct Membranes, namely, the external 2 from the Peritonæum, the middle one confisting of various musculous 3 Fibres, and the internal Tunic furnished with mucous 4 Glands which prevent this membranous Receptacle from being eroded by the acrid 5 and stagnating Urine. A great Number of Blood-veffels are also di-Stributed throughout the Membranes of this Receptacle, in a particular Course or Direction different from that in which the Vessels run either in the Skin, Kidneys, Spleen, Liver, or any other Part. When therefore the Urine excites a painful or an uneasy Sensation by its Acrimony, Quantity, or long Retention, by which it erodes, diftends or irritates the contiguous Membranes, by abrading 6 their Mucus; that uneafy Sensation excites the Motion

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of the several Parts which we before explained, (§. 111.) whereby all the Contents of the Abdomen are urged or pressed with a considerable Force 7, returned by the Lamella of the Peritonæum extended over the Pelvis upon the Bladder itself; which meeting with less Resistance in its lower Part at that time, the Urine is therefore expelled downward with a confiderable Force and through the Opening or Neck of the Bladder which it extends, preffes the circumjacent Vessels, and overcomes 8 the Refistance of the orbicular or arched Sphincter; which Sphincter is feated in the upper Part of the Neck of the Bladder above the prostate Gland, under the external longitudinal Fibres of the muscular Coat of the Bladder, the transverse fleshy Fibres of this Sphincter being not very thick: by this Force therefore the Urine is drove into the Cavity of the Urethra, lubricated and defended with an oily foft Mucus, which always flows plentifully from the Ducts of Cowper 9 and Morgagni; which Urethra descending from the Bladder in a winding Course, rises up again in a Curve, and then descends, being of different Diameters 10 or Capacities in different Parts of its Course, and invested all the way with a cavernous and spongy 11 Duct, through which it passes; so that the Urethra being flaccid at the time of this Action (§. 111.), the Urine is evacuated through it from the Body.

The Pelvis is the fourth remarkable Cavity of the Trunk, comprehended betwixt the Os facrum and

and Coccyx behind, before by the Os pubis, and laterally by the Offa ilia, being partitioned off above from the Abdomen by the Peritonæum, nor is it compressed by any of the abdominal Muscles. In the Cavity of this Pelvis are placed the Intestinum Rectum and Bladder, and the Uterus in Women. But all the Viscera seated in the Pelvis fuffer a Compression from the Diaphragm and abdominal Muscles, by which the abdominal Viscera being pressed downward, communicate the fame Pressure to the Viscera of the Pelvis, and efpecially to the distended Bladder, which finding a less Resistance in the Urethra than in any other Point, the Urine can only flow out that way. How confiderable is the Force of this Preffure exerted in the Pelvis, may appear from the Endeayours of Women in Labour; but the Bladder is pressed equally with the same Force as the Uterus; fince the abdominal Viscera descending are urged against the Bladder, or rather against the convex Part of the Peritonæum with which it is covered, while the Peritonæum at the fame time rifes up with the Bladder and forms a Concavity. But the Peritonæum does not contain or invest the Bladder. covering only its Fundus or upper Part, which ought to be particularly observed in performing the high Operation of the Stone, according to Peter Francus, namely, by distending the Bladder so as to make it rife up in the Cavity of the Abdomen, whereas when it is empty, it deferts the Abdomen and contracts itself down to the Bottom of the Pelvis.

2 There are two Lamellæ of the Peritonæum, namely, the Peritonæum properly so called, and the cellular Membrane which lies on the Outfide of it; but it is the latter only which invests the whole Bladder, and the Peritonæum strictly speaking only covers the Fundus or upper Part of the

Bladder, as we observed before.

3 Anatomists usually ascribe a single Strata of Fibres in the Bladder, continued longitudinally from the Fundus to its Neck or Sphincter, by which it is supposed to antagonize or contract itfelf again. But this is not fufficient to explain the beautiful Fabric of this muscular Receptacle. For the Bladder in a healthy Person is required to be so distensible, as to contain fix, eight, ten, or more Ounces of Water; and again to be capable of contracting itself, so as to be scarce capable of receiving a Filberd-nut: and in this Variation it is necessary for the Bladder to continue changing its Figure and Capacity every Moment by the diffending Power of the Urine, and the contractile Force of its muscular Fabric. To effect this, Nature has supplied the Bladder with many Radii or muscular Fibres, extending themselves in all Directions throughout the Bladder. Even Eustachius has represented something of this Fabric in the Figure of the Bladder, which has not been observed by his Interpreters. Ruysch tells us, that the Distribution of the Vessels in the Coats of the Bladder, is very different from their Course in any other Part of the Body; and the same Anatomist also demonstrated the various muscular Radii or Intersections of Fibres in this Part, even before the anatomical Tables of Eustachius were found. There is also fomething of the fame Fabric in the Membrane of the Tympanum, where the Fibres and Arteries. are distributed from the Center towards the Circumference; because it is required to be capable of various Degrees of Tension and Relaxation like the Bladder. How confiderable a Force is exerted by this Contraction of the Bladder, may appear from fome Experiments which are made on Dogs and

and Cats, as also from too long a Retention of the Urine in those who are accustomed to be over modest. In a Dog who retained his Urine three Days by a Ligature, upon turning him loose no Evacuation followed; I therefore made a small Wound through the Bladder, and the Urine slew up to a considerable Height, the Bladder itself contracting to such a degree, that there was scarce

the least Cavity remained.

\*The Innocency of this Mucus was first demonstrated in Opposition to the Schools by Helmont, who afferted that it did not afford the Matter of the Stone, but was formed for lubricating the Parts, and easing the Pains; since the Mucus arrives more plentifully, as the Stone is larger and more rough, and irritating to the Bladder, in the same manner as provident Nature supplies Tears to the Eyes, to wash off any contiguous Matter. In short, there are some Instances where eight Ounces of this Mucus has been evacuated in a Day.

How intolerable the Pain is, arifing from the Acrimony and Retention of the Urine, those are well acquainted, who through Modesty have sometimes retained their Urine long beyond the sea-sonable time. Tiberius, who was a Tyrant not of the common Stamp, and extremely ingenious in torturing his Enemies, tied up the Urethra in those whom he hated most, after first obliging

them to drink a large Quantity of Water.

of the least Part of the Bladder is deprived of this Mucus, a Strangury follows, namely, as soon as a Drop of the Urine touches the sensible or nervous Fibres, which are not cloathed with their Mucus, an irresistible Inclination for voiding the Urine follows, which cannot be governed by any Influence of the Will, but the offending Drops of I 4

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forts of Respiration.

This Force is not necessary, if there are but a few Drops of Urine, for then they may be discharged almost spontaneously; but if the Bladder is extremely sull, the Urine cannot be voided until a few Drops are first expressed with a considerable Force, and then the rest of the Urine sollows

almost spontaneously.

<sup>8</sup> The Sphincter Muscle closes the Neck of the Bladder fo firmly, that notwithstanding there is a free Passage almost sufficient to admit the Finger, and sometimes even to discharge Stones that are much larger, when the Bladder is full, and the Parts lubricated with Mucus; yet so great is the Contraction in a natural State, that not the leaft Drop of the Urine can escape, until some Part of it is forced out by the Contraction of the Diaphragm and abdominal Muscles: and then, as Water flowing from a larger to a narrower Receptacle, presses the converging Sides with a considerable Force, the Nerves of the Sphincter will be thus compressed, overcome, and relaxed, so that all the remaining Urine will meet with an eafy Paffage with little or no Force to urge it, and yet does the Urine flow out with fuch an Impetus, as fometimes to throw out a Stone against the Wall with such a Noise, as if it was discharged by a Machine. It is a Piece of good Advice for those People who are afflicted with a Calculus lodged in the Orifice of the Urethra, to retain their Urine as long as they are able, and then of a fudden to use all their Endeavours to discharge it at one Instant, by which means Stones of a very large Size have been often discharged. Hence therefore a Fœtus cannot discharge any Urine before it has breathed (§. 684.) So exquifite a Guard has Nature placed upon this Part, though framed of such soft and tender Materials, that the utmost Art of Mechanicks can scarce produce the same Mechanism

by the working up of Metals.

10 The Urethra paffing out of the Bladder is at first very narrow, and from thence to the ejaculatory Muscles, into which Part the Semen is poured, it is the largest of all, being denominated in this place the Bulb of the Urethra. In the fecond place, it is contracted from the Infertion of the suspensory Ligament where the Penis is inflected, and from thence goes on cylindrically, keeping the fame Diameter, till it at length dilates again in the Glans, and at last converges at its Termination in the Extremity of the Glans, which makes the third and last Stricture. are therefore three Dilatations and as many Strictures in the Urethra, at all which last a Calculus may stop and torture the Patient. In Women the Urethra is very short, and has but one Stricture. In those lamentable Cases, where a Calculus stops at any of the aforementioned Strictures in the male Urethra, one of the best Remedies is to inject Oil of fweet Almonds, and then to thrust forward the Stone through the Passage which has been lubricated by the Oil. The ancient Egyptians had a Method of discharging a Calculus in the Urethra by inflating and distending that Canal in the Penis, fo as that the Calculus might be drove forward by the Fingers; which is certainly one of the best Methods, provided the Urethra has been first lubricated with Oil.

9 This Mucus is extremely necessary for preventing the Sides of the Urethra from collapsing or adhering in the time of Sleep, or whenever the Urine has been retained for a long time; which deplorable Disorder I have sometimes seen accompanied

by the folitary Glands of Cowper, which he discover'd. As also in the pendulous Part of the Urethra, it is discharged by numerous Follicles or Drains, observed by Morgagni and Fantoni, unless any one chuses to call them by a different Name.

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our strictest Attention, more especially the Ducts of Cowper, in which a Gonorrhæa of a long standing usually sixes its Seat, at least in our Times. An Ulceration of the Substance of these Glands occasions a most obstinate internal Gonorrhæa, in which Fistulæ arise discharging a contagious Matter.

§. 367. So foon as this 1 Action (§. 366.) ceases, the Fibres of the Sphineter 2 Muscle contract themselves by their natural Force, as being no longer compressed; by which means the Neck of the Bladder is close shut, and then the Muscles which ejaculate the Urine in Men press out what remains in the Urethra: for as these Muscles arise from the upper and external Part of the Urethra under the Os Pubis, where their Tendons departing from each other are inferted into the cavernous Bodies of the Penis, and invest that Part of the Urethra, which coming out from the Bladder is the largest of all, and invested with its proper cavernous Body; while the Corpora cavernosa of the Penis have not as yet united together externally: here these Muscles uniting below, go on to the Perinæum, where they feem to become tendinous, and to combine strongly in a manner with the transverse Muscles of the Penis, fixing themselves into the Root or Bulb of the Urethra; from whence one may eafily understand their Action 3, which being abolished in old Men 4, they are troubled with a dripping after making Water, and a sharp corroding Pain follows from the retained Urine.

This is also accompanied with the muscular Contraction of the Bladder itself, by which it is reduced from a large Capacity to a small Globe. fo as to evacuate all its contained Urine into the Urethra.

<sup>2</sup> So foon as the Urine is forced out through the Mouth of the Urethra, no Cause then remains to compress and relax the Sphincter: nor has this Muscle any Antagonist at that time; and therefore the Sphincter recovering itself, shuts close the Neck of the Bladder as at first.

Which Action is to constringe the back Part of the Urethra, fo as to protrude both the Urine and the Semen out of that Canal; the last of which is poured into the Urethra through the Mouths or Eyes of the Caput Gallinaginis. To this Action also add the single Muscle of M. Littre, which is placed betwixt the Bulb of the Urethra.

and the Sphineter ani.

4 The ejaculatory Muscles which throw out the Urine, are always stronger in proportion as the Person is younger; whereas in old Age they become almost paralytic, whence their Impotency. And the fame holds true with respect to the Penis in all other Animals. Hence in young Men the Urine is discharged in a full Stream to a considerable Distance; but in old Men it is thrown to a ve-

ry small Distance, and in a broken Stream. There are also many Drops of the Urine which remain in the Bulb of the Urethra before it enters betwixt the Bodies of the Corpora cavernofa; and this Urine being retained for want of Strength in the Accelerator Muscles stagnates, becomes acrimonious, and excites an incurable painful Strangury, as Hippocrates formerly observed, to be relieved by no oily Medicines. In that Case the only Relief that. remains, is for the Patient to squeeze forward the remaining Drops of Urine from the back Part of the Urethra with his Hand or Fingers: for by this means imitating Nature, ten or twelve Drops of Urine are expressed, which if retained would have occasioned great Uneasiness. And in this we have a notable Instance how easily a Disorder may be cured, when we are acquainted with its Nature and Cause.

§. 368. But the Urine itself is of so many 1 Sorts, that we ought first to distinguish them before we can say any thing justly concerning its Nature.

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Paracelfus, in his rough and obscure Diction, was the first who with Judgment proposed this Distinction. In general, we call the Urine all that Liquor which is evacuated from the Urethra of a healthy Person, except only the Semen and its mucous Vehicle, which naturally subricates the Urethra. But although the Urine is properly an Excrement, yet the Consideration of it is extremely necessary to a Physician, who ought to consider it almost in every Disease, as a Messenger relating to him what is suffer'd by the Blood within the Vessels.

§. 369. For after plentiful drinking 1 of watery Liquors, the Urine is crude, much in Quantity, mild or infipid, inodorous and almost without Colour, of a watery Nature, and may be retained in the Bladder without Uneafiness.

Paracelfus calls the Urine Drink, evacuated in proportion to the Quantity of Liquor taken into the Stomach, of a watery Confistence, infipid, and almost inodorous. I have repeated several Experiments both on myself and Friends in respect to the Urine. If a healthy Person makes Water while fasting, and so soon as out of Bed, the Urine appears concocted, has a Smell, a bitter Saltness, and a high yellow Colour: if now the Person drinks half a Pint of warm Spring-water, he will in a quarter of an Hour's time discharge Urine almost inodorous, and more nearly refembling Water; if again after this as much more warm Water be drank, the Urine will be voided almost without Colour or Smell, and without any Sediment. thus Water is continued to be drank in this manner, as I have fometimes done myself ten times, at last the Water will be discharged little or nothing alter'd, flowing from the Bladder as through a Funnel, and with fo great an Inclination to Excretion, as will scarce permit the Mind to influence the retentive Organs. From this Experiment it appears, that so much Water may be taken into the Body, as will produce a continual Succession of Liquor flowing from the Stomach through all the Vessels in one continued Thread to the Bladder; and that at length becoming gradually thinner, it is at last voided almost crude, with little or no oily or

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faline Parts, so that by this means all the stony Matter may be washed out from the Blood. Even a considerable time after I had left off drinking the Water, the Urine continued very watery and limpid for a considerable time, and therefore a Physician can conclude nothing from such Urine as we have here described.

§. 370. But the Urine which is voided after the Chyle is formed, appears more concocted, less in Quantity, more acrid, saline, a little feetid, of a light yellow, or pale sulphur Colour, being not so easily retained in the Bladder.

Another Species of Urine according to Paracelfus is that of the Chyle. The Chyle is not immediately converted into Blood after entering the Veins, but it circulates together with the Blood, and is continually supplied with more Chyle for above eight Hours after a Meal, according to Lower and Wallis, allowing an Hour or two Variation for the Difference of Strength in the digestive Organs of different People. Even after the Chyle has been changed into Milk, it circulates with the Blood under that Form for the Space of twelve Hours before it is turned into Serum. I knew a Nurse who was supplied with good Milk in her Breasts, even twelve Hours after she had eat any thing, and without drinking in the mean time, the Milk flowing fresh from the Arteries into the lactiferous Ducts of the Nipple; but this is not often to be met with. But if the Milk is confined a longer Time in the Body, it turns yellow, grows bitter, and is refused by the Infant, for in that Time it begins to change into the Serum of the Blood. As long

long as the Chyle is not yet converted into Blood. the Urine which is then avoided, is by Paracelsus termed the Urine of the Chyle, and it then in a great measure retains something of the Nature of the Food or Aliment which the Person took last: for by Aliments only we may make or imitate all the Kinds of Urine, which are observed in acute Diseases. The eating of Rhubarb and Saffron renders the Urine like that of an ardent Fever, and Tamarinds turn the Urine green; whereas Caffia and Asparagus make it black and fœtid, like the Urine which is voided after a Gangrene in some The Urine which is renof the internal Parts. dered some time after a plentiful Use of Oil of Almonds, determined towards the Kidneys by Caffia, looks purulent, as if it contained Matter. From hence we conclude, that neither this Urine of the Chyle is to be trufted as a faithful Messenger indicating the State of the Blood.

§. 371. But again the Urine which is difcharged after the Chyle has been converted into Serum, appears more of a yellow or straw Colour, more concocted, reddifh, small in Quantity, faline, fœtid, acrid, and very stimulating, infomuch that it cannot be long retained in the Bladder.

That Urine which is discharged about twelve Hours after a Meal, (by which time the Milk of the Chyle turns into Serum of the Blood-according to the Observation of Lower, being derived from the yellow Serum) is doubtless a more faithful Witness, and indicates more of the Nature of the Blood than any other Urine; it is acrid and cannot be long retained because it stimulates the Bladder to Excretion.

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§. 372. But finally, the Urine which is made after long 1 fasting, when no Drink has been taken for a considerable time, is derived from the Humours which have been a long time powerfully rubbed together 2, and also from the solid Parts which have been broke off by the same Attrition; and this last mentioned Urine is the smallest in Quantity, very sharp, saline 3, society, very red, and scarce retainable in the Bladder, it is also sound very much inclined to Putrefaction.

If the most healthy Person gives himself up to Sleep after Supper, without drinking all Night and without taking any Breakfast in the Morning, he will avoid the Urine which was collected over Night, but the next Urine which he voids immediately after, will be more fœtid, bitter and high coloured, containing generally more of the calculous Matter, and at length by long Abstinence only, inflicted either by Poverty or fome religious Command, the Urine becomes fo acrimonious after twenty-four Hours as to produce a Strangury. Hunger hardly kills of itself, until it has been continued for a long time; a Person may support Life with mere Water for twenty Days without taking any Food; for Water will wash out the acrid Parts of the Blood, which being retained would destroy the Brain; and therefore those who perish with Hunger do not expire fo much for want of Aliment as for want of washing out the Acrimony of the Humours which Abstinence creates. When Charles V. carried on a War in the scorching Regions of Africa, a great Number of his Soldiers perished daily, till at length the Scarcity of Water performed performed more than the Arms of the Enemy were capable of; for Soldiers foon perish if they are destirute of Water. We read formerly that Jacob and Elau, two Brothers, accompanying each other in their Journey, faid one to the other from Experience, that if the Flock was to be tired by driving even half a Day in the hot Sun they would perish. For barely by the vital Heat and Attrition, the unctuous Humours which defend our Vessels, with the Mucus of the urinary Passages are quite destroyed, the oily Parts of the Blood turn rank, the Saliva and Bile acquire a corrofive Nature, the Urine becomes quite alcaline, and the Salts of the Blood itself become acrid or alcaline from their natural State, as Tschirnbausen has formerly demonstrated.

All this happens in a little time in acute Difeases. For the Heat and Attrition of the Humours are very intense, so as to render the Urine ardent or scalding as it is termed, of a flame Colour, very acrid, scetid and full of Scales or Fleeces of Mucus, obliging the Patient to evacuate it almost every Moment, as Hippocrates formerly observed: hereupon the Appetite to Food ceases, a Nausea and Vomiting follow, and in the most acute Diseases a Quinfy and Hydrophobia; in which, Water itself is abhorred, or any other Drink. But the common Cause of all these Phænomena, is that Acrimony and Alteration of the Humours which we before described.

The natural Salts of the human Body approach the Nature of Sal Ammoniacum, and no wonder fince Sal Ammoniacum is composed of Urine or Dung with the Addition of Sea Salt.

- §. 373. From hence therefore we may be able to answer, why Urine is discharged (like that at §. 372.) after great Heat, violent Exercife, profuse Sweating, or Abstinence from Drink? And also why the Urine appears the Reverse under opposite Circumstances?
- §. 374. Why the Urine appears thinner, more acrid 1, fætid 2 and saline 3 than the Blood itself?
- If we enquire after the final Reason why the Urine is fo acrid, the following may be given. As the Creator made Man an active Animal to be continually in Exercise, and at the same time to last or survive for many Years, since there is no Animal that easily outlives Man; and there are some Men who live to a hundred and fifty Years of Age, which can be faid of no other Animal. But in the continual Exercises and Motions of Life, our Humours do by unavoidable Necessity become attenuated fo as to exhale, whence Supplies of new Matter to the Body become necessary, that is, from the Aliments which in general are taken either from Vegetables or Animals. But all Plants, and much more all Animals, do by a Heat equal to that of the human Body, putrefy in eleven or twelve Days time, and turn into a most fœtid Excrement. If fuch a Change was to be made in the constituent Parts of our Bodies, and the acrid Humours were not to be discharged before they were perfectly corrupted, our tender Machines would foon be destroy'd. There are therefore Cisterns and Receptacles in the human Body, wherein to deposit those Parts of our Humours which are become acrid and nearly inclined to Putrefaction,

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that they may be at length discharged from the Body, as a foul and pernicious Matter. Of this nature are the Kidneys and Bladder, together with the Liquor which washes out the putrid and lixivial Parts of the Blood and Humours, which we call by the Name of Urine. The Necessity of drinking never leaves us, fo long as any Salts remain unsheath'd in the Body. But the Excretion of the Urine is so necessary, that a Retention of it for twelve or fourteen Days has proved quite destructive to Life: not from a Retention of the Drink distending the Vessels and Viscera, for that might have been remedied by Abstinence; nor yet because the Quantity of the Blood was too much increased by the continual Addition of new Chyle; which Diforder might have been remedied by bleeding and purging; therefore the only Caufe of Death is the acrid Lixivium of the Urine retained in the Blood, and destroying the tender Fabric of the Brain. Hence it is that before Death in those who perish by a Suppression of Urine, the Functions of the Brain are always diffurbed, and Death itself is brought on by an Apoplexy: for the oily Parts of the Urine being continually fomented by Heat and Attrition, acquire an incorrigible Acrimony.

All fœtid Smells arise from Oil, as we are taught by Chemistry. But Oil which is thick and solid like Fat, is not at all fœtid; whereas if it be attenuated by Heat and Attrition, it becomes yellow, acrid, and very fœtid. But of this nature is all the Oil contained in the Urine, which is become miscible with Water, after being attenuated by a long Circulation through the Vessels. But if Urine is discharged mild and sweet, or milky, as

in a Diabetes, Death is then near at hand.

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<sup>3</sup> There is not any Humour in the whole Body. whose Saltness comes up to that of the Urine; the Chyle, Milk, Serum of the Blood, Blood itself, Mucus, Semen, &c. are all sweet and inoffensive. The Tears indeed are falt, though not immoderately fo; but if they continue to flow over the Cheek for a long time together, they excoriate and excite an Inflammation in the Eyes and Skin. The Sweats which are forced out by hard Labour, indeed partake of Acrimony, but not so as to be injurious thereby. The Bile comes nearest to the Urine in Strength of Acrimony, and yet it is much milder, as appears from the Bile not injuring the Eye when sprinkled into it; for the Gall of an Eel is frequently applied to the Eyes with confiderable Advantage, without caufing any great Pain or Uneafiness, whereas Urine inflames the naked Eye. It is also demonstrated from a chemical Analysis, that there is no Humour in the Body which contains so large a Quantity of Salt, as the Urine affords by Distillation. For the Salts of the human Body do not naturally exist under the Shape of Salts, but they are drawn out, separated, or made by Putrefaction, or an Attrition of the Humours.

§. 375. The Urine therefore contains not only the watery, but also the faline, oily and earthy 4 Parts of the Blood; it contains those Salts which are most acrid, subtilized, volatile, and nearly alcaline; it contains those Oils which are most attenuated, volatilized, rancid or acrimonious, and nearly approaching to a State of Putrefaction; it contains also the Particles of Earth, which are extremely subtle,

# § 375. Action of the Bladder. 133 in a great measure volatile, and much divided by Attrition.

The greatest Part of the Urine is truly watery, and therefore the Urine washes out all those oily, saline, and earthy Parts of the Blood, which would be injurious or destructive to the Body.

We all abhor putrid or stinking Food; but it is to that State which all our Humours incline, unless the Urine washes out all the Salts before they become quite volatile: for in reality there is never any truly volatile Salt in any of the animal Humours; nor in the Urine itself is there so much as a single Grain of volatile Salt to be sound while in its natural State, as I have long ago demonstrated; see Process 92 and 94 of our Chemistry.

<sup>3</sup> All that gives Smell or Colour to the Urine is the Oil; for neither Salt nor Earth have a fœtid Smell, nor any Colour when they are pure. Nor is this at all wonderful; for the mildest Oil, even the Cream of Milk, which is so white, being fried in a Pan turns bitter, and acquires an empyreumatic Smell; and therefore the more the Oil is attenuated by Heat and Attrition, so much the redder and higher coloured will the Urine be, even down to Blackness.

Quantity of Earth lies concealed in the most limpid Urine: but this Truth was first discover'd by Helmont. He distilled Urine several times, till at the Approach of Easter he desisted in Reverence to the Time; but after the Expiration of three Days, he returned to work at his beloved Furnaces: he found that the Retort in which he had distilled the Urine, was incrusted on all sides with a kind of Earth or tartarious Matter. Upon another time, after exposing Urine to Putresaction in K 3

a gentle Heat in a very tall glass Body, he exhaled a very limpid Water, which left behind a dry, fimple, infipid, and inodorous Earth; and therefore he concluded from these and other Experiments, that there was a very fubtle and volatile Earth mixed with the Urine, capable of rifing into Vapours with a gentle Heat; and that this Earth, upon the Accession of any coagulating Cause, produced the Stone. Even in the most subtle Spirit of Urine, as also in all Waters and Oils, there is an Earth concealed, though it is frequently difficult to separate it. I myself set by some Spirits of Urine in Glaffes very exactly closed, in which it flood for many Years, and at length it deposited a white volatile Earth. But this is really a true Earth, dry, folid, and unchangeable, being those Particles which compose the folid Basis of all the Fibres and Vessels in the Body, as I demonstrated in the Year 1702. This Earth is the only Substance that remains after burning the Bodies of Animals, and being infipid, white, and very fixed in the Fire, it affords the best Matter for making of Veffels in which Silver is refined. The Glue which connects the Parts of this Earth is oily. which with an intense Fire partly exhales, and in part turns into Phosphorus. This same Earth is tore off from the folid Fibres of the Body by the Impulse of the circulating Humours, and returning into the Blood, it is carried into and discharg. ed from the Kidneys by the Urine. There is therefore great Plenty of that Matter in the Urine, which is apt to form the Stone. And even the Stone itself is formed of the Matter of the small Veffels of the Body, which has been abraded by the Vis Vitæ, and deposited through the Kidneys: and instead of that earthy Matter which is continually abraded, a new subtilized Earth is constantly supplied from the Aliments, to preserve the Machine of the human Body from Diffolution.

§. 376. But in the watery Part of the Urine there is a very fubtle, volatile and fœtid Oil1, altogether of a particular Odour, which strongly adheres to the Water, being first so highly attenuated that it may be intimately mixed therewith, and can be afterwards very difficultly feparated; it may therefore perhaps be not improperly termed a Spirit?

The recent Urine which has been discharged fome time after the Concoction of the Aliment has been performed finells fœtid; and if it be distilled over a hundred times, there will always remain fomething fœtid. There is therefore an Oil in the Urine which manifests itself by no other Appearance than that of a fœtid Smell. If the Urine is permitted to stand at rest, its fœtid Smell continually increases, and if the more sluid Parts of it are drawn over by Distillation, even that distilled Water of the Urine will be fœtid: But yet the Urine which is voided by those who drink Plenty of Punch and Malt Liquor is destitute of this fœtid Smell. It may be therefore asked, whether or no this fœtid Water may not pass under the Denomination of a Spirit? For what are Spirits more than Oil attenuated and mixed with Water? But as for an inflammable Spirit, I could never obtain the least Quantity even from above a hundred Pints of distilled Urine. Nor could I ever observe that Fermentation of the Urine which Helmont describes. fo as to burft the Glasses by the spontaneous working of it; but perhaps Helmont might have repofited his Urine in a Cask in which Wine had formerly

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merly been contained, many Parts of which being absorbed by the Wood might cause a Fermentation.

§. 377. The natural Salt: of the Urine is faponaceous 2, and nearly akin to Sal Ammoniacum 3, from which it differs notwithstanding its Alcali being more easily separable; it also contains some fixed 4 or Sea Salt, which is chiefly derived from the common Salt of our Aliments: therefore the Salt of the Urine is neither acid 5, alcaline 6, muriatic 7, nor ammoniacal, but of a peculiar Nature or Disposition, being perfectly white when it is unmixed.

A Salt may be prepared from the Urine of the human Body differing from all other Salts in the whole Field of Nature; and if any Salt deserves the Title of effential, it is certainly this of the Urine: for an effential Salt is properly one obtained from the Juices of Vegetables by a Crystallization without the Force of Fire. But it is no wonder that such a Salt should be found in the Urine, fince that and all the other Humours in the Body are prepared from Vegetables: but this Salt of the Urine is nevertheless very different from all others, which are obtained from any folid or fluid Parts of the human Body by Fire or Putrefaction; for those Salts are alcaline and caustic, of which nature there are none naturally in the Humours of the Body. But the Salt we now speak of as essential, is that which the Humours of a healthy Body have transfused or dissolved in Water, which circulates together with the Humours, and passes afterwards together with its Salts through the Kidneys without any Alteration, excepting only that it is deprived

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of its Water by Inspissation. Nor is there any Humour of the Body, however infipid, but what contains a Salt of this nature.

<sup>2</sup> Composed of an Oil and lixivious Salt miscible with Water; fuch a Salt is faponaceous: but of this nature is the effential Salt of the Urine composed of an attenuated Oil mixed with Water, infomuch that there is no healthy Urine without a Portion of Oil in it intimately combined with the Water. But the Salt of Urine has a notable faponaceous and deterfive Quality, as is evident not only from its mechanical Uses for scowering, but also from its diuretic Quality as a Medicine; for if Salt of Urine be dissolved and drank in Water of a Morning fafting, after Exercise, it proves highly diuretic.

3 The Sal Ammoniacum fo called, remains immutable even after it has been fublimed by itself. or distilled with Water above a hundred times; whereas our animal Salts, as that of the Urine, immediately turn into an alcaline Nature upon the

first Attack with the Fire.

About thirty Years ago, namely, in the Year 1696, I was surprised to find that the Salt of Urine, mixed with Spirits of Nitre, should compose an Aqua regia capable of diffolving Gold; and the very same Effect had Urine, even after it had stood exposed for many Years to Putrefaction, or even after it had been tortured with a Fire fo violent as to produce the Phosphorus. But I afterwards found that it was the pure Sea Salt in the Urine which formed the Aqua regia, which Salt being continually taken in with our Aliments, paffes through all the Vessels and Organs of the Body without ever receiving any Alteration, as Helmont formerly well observed; from whence he recommends it against the Stone. But this Salt is not to be found in the Urine of those Animals who

take in no Sea Salt, as Oxen, Sheep, &c.

5 Homberg imagin'd he had demonstrated an Acid, when by forming a Lixivium of the calcined Ashes obtained from several hundred Weight of Blood, he from thence obtained a very small Quantity of Salt, which being mixed with three times as much Earth, and distilled with a most intense Fire, yielded an acid Spirit into the Receiver. But this was certainly obtained from the Sea Salt, fince the Spirit would make Aqua regia like that of common Salt. But neither is an Acid natural to the human Body, fince it arises only from the Aliments, nor does it exist as an Acid while circulating with our Humours; but it is only produced by the Force of Fire from its natural State, which is not acid.

6 In this University it was formerly taught, that the human Salts were of an alcaline Nature; but it is now thirty Years ago (namely, in 1696) fince I demonstrated, that our Salts were neither alcaline, nor made any Effervescence with acid Liquors. It is indeed true, that Fire and Putrefaction form a Salt truly lixivial, as well from the Parts of Vegetables as Animals; but then fuch a Salt is the Product of the Fire, and did not before exist as such. Nor is there any volatile Salt naturally residing in the human Body, that is, no Salt which will ascend with a degree of Heat no greater than that of boiling Water.

<sup>7</sup> By muriatic Salt we understand the common Rock or Sea Salt diffolved in Water; and of this kind there is a fmall Quantity in the Urine, but no more than what is adventitious, or taken in

with the Aliments.

§. 378. The Oil of the Urine, produced from the Fat attenuated by Attrition, appears to be simple, and of a peculiar Kind, differing from all other Oils; notwithstanding it may feem at first to be of a different Nature from the different Proportions of Salt and Earth with which it is mixed; and it is from this Oil only that the Urine derives its Colour, and not from the Bile.

The Oil is that Part which gives Colour to the Urine; but this is no more than the animal Fat dissolved and attenuated by Attrition. Every Animal, even though fed barely by Water and Grass, will from thence derive Milk, whose Cream may be formed into a congealed Oil, which we call Butter: fo that no Animal is destitute of Fat. Part of which being more fluid than the reft, cir culates with the Blood, while the other Parts are deposited in the Cells of the adipose Membrane. Now that Part of the Fat which circulates with the Blood does, by the continual Heat and Attrition. pass through various Degrees of Attenuation, by which its Appearance is alter'd into a yellow, red, or flame Colour, as we fee it appears when difcharged in the Urine. Even the citron Colour of healthy Blood arises, in a great measure, from a determinate Quantity of Oil. When the Urine appears red, it is a Sign that the Heat of the Body is increased beyond its healthy Degree, by which the Oil is more highly attenuated and intimately mixed with the Urine than it naturally ought to be. But that the Colour of the Urine arises from the Oil is demonstrable, inafmuch as that which was discharged in the Morning appears concocted; whereas

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whereas after drinking, the Urine becomes gradually more pale, and deposits the Taste which it had in proportion to the Quantity of Water drank. But now this most pale Urine will recover both the Smell and Taste of its Oil barely by standing a few Hours, by which time the Oil may become so attenuated as to mix intimately with the Water, which is absolutely necessary in order for it to tinge the Urine. And this Oil is some of the thinnest in the whole Body. But fometimes the fat Oil, which is deposited in the Cells of the adipose Membrane, returns again into the Blood, and by a more violent Attrition in the Vessels, it tinges the Urine with that flame Colour and feetid Smell which we observe in Fevers, which sometimes so emaciate or waste the Fat of the Body, that Ruysch observes in an Epistle to me, that a Patient weighed thirty Pounds lighter; and Lister extends his Observation even to eighty Pounds.

§ 379. The Earth 1 of the Urine appears fo highly attenuated and intricately mixed with the rest of the Principles, as to be quite conceased in them; but it lies hid frequently invisible, in a volatile and subtle State both in the Water, Spirits, Salt and Oil; and when separated from them, it appears simple or uncompounded, white 2, fixed, insoluble in Water, insipid, and inodorous.

It is usually one of the Characteristics in the Definition of Earth, that it is not dissolvable in Water: but this is true only of those grosser Particles of the Earth which are conspicuous to the Eye; for it may be so attenuated as to become colourless and invisible while it floats in a pellucid Liquor,

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Liquor, though it is nevertheless the same immutable Earth. The British Chalk and Tobacco-pipe Clay are to be enumerated among those Bodies which are the least alterable; for they only sustain the Violence of the folar Fire in the Focus of the burning Lens of Tschirnbausen, when at the same time Gold and Silver are volatilized and exhaled. But this same Chalk may be so suspended in a pellucid Liquor as to be invisible to the Eye, namely, in distilled Vinegar: but if to the same saturated Vinegar you pour Oil of Tartar per deliquium, you will be furprized to fee the Earth renew its Appearance, and subside in little Fleeces to the Bottom of the Vessel without having suffered any manner of Alteration in its Nature. A Person has no Reason to be afraid of spoiling the pellucid Colour of Water which the Earth feems to obscure; for even the most crystalline Glass itself, which is the most pellucid of solid Bodies, is formed merely of Earth and Salt combined by the violent Action of the Fire.

<sup>2</sup> All pure Earth is white, and if ever Earth appears of some Colour, it is almost constantly tinged with Iron, which is a Metal abounding with Sulphur, and lies concealed almost in all Sorts of Clay. But this Earth of the Urine is an Affemblage of the folid Elements or constiuent Particles of the folid Fibres in the human Body, several of which being connected together form one of the most simple Fibres; therefore each of these Particles are invisible alone, but become conspicuous when several of them are joined together into a Mass by the Intervention of a glutinous Substance; but this connesting Glue resides in all organic or living Bodies, more especially in Plants, in which it so firmly connects those folid Elements together, that they are not separable but by the most intense Action of

of Fire. These elementary Particles of the Solids, many of which compose the folid Fibres, being continually abraded by the Impulse of the circulating Humours, return into the Veins and Heart; from whence they are deposited almost no where but in the Kidneys, through which this Earth is washed out with the Urine, a Liquor more replenished with Earth than any other Humour in the Body: for we fee this Earth deposit itself from the Urine of the most healthy Person to the Sides and Bottom of the containing Veffel; and even the Blood itself is not wholly destitute of earthy Particles, nor is there any folid or fluid Part of the Body which after Calcination does not afford a most pure and white Earth. But even this Earth itself is the Matter of Calculi, whose chief Residence is in the Kidneys, which alone free the Blood from the Minerals productive of this lamentable Diforder. It is therefore fufficiently evident, that a found State of the Kidneys is effentially necessary to produce a firm and healthy Condition of the Body.

§. 380. But we observe that neither the nutritious or well digested Serum, nor good Chyle itself, or Milk 2, are ever found in the Urine in a natural State. But how are these Juices prevented from escaping? Is it not from their Thickness in Conjunction with the Smallness and Convolutions of the uriniferous Vessels?

A certain celebrated Professor of Chemistry publickly taught, that the Serum of the Blood was to be found in the Urine; but in order to be fatisfied of this Point, I examined above a hundred Pints of Urine, but never could see that it contain-

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ed any thing which would congeal like the white of an Egg by the boiling of Water. In the Year 1725 I collected a whole Cask full of Urine, which I inspiffated till a hundred Pounds were reduced to one, for I was about to prepare the Phofphorus, but yet I could never find any thing in the Urine which would cut like a boiled Egg. But the Reafon why none of the hardening Humours pass through the renal Ducts, feems to arise from their Smallness with the compact Texture of the Kidneys, preventing their too easy Dilatation, affifted by the Mæanders or serpentine Course of the Arteries; each of which feems to be an Obstacle preventing Liquors, which are so thick as the Serum of the Blood, from passing through the uriniferous Ducts.

<sup>2</sup> There was a certain Woman who dwelt at the City of Dort, who bore and fuckled Children for twelve Years successively; but at length she fell into a lacteal Diabetes, in which all the Nourishment that was taken ran through her Breasts without any Suction, under the Appearance of Milk, infomuch that if she drank a Pint of Ale there was almost the like Quantity of Milk evacuated from her Breasts: but after nine Months Affliction with this Diforder she was at length cured, but yet this Woman never deposited any thing of Milk in her Urine. However, the renal Ducts are sometimes fo much relaxed by the Abuse of warm watery Liquors, or otherwise, that they even transmit the Milk or Chyle itself, producing a lacteal Diabetes, which foon destroys the Patient with an Atrophy. But the Reason why the Milk does not naturally pass this way, seems to depend much upon the Difference of the Orifices of the lacteal Veffels from those of the uriniferous Ducts: we see that the Breasts are so alterable, that in Nurses they are furprifingly furprisingly distended; but after they have been exhausted of the Milk by the Infant, they are reduced to a very small Compass; whereas the Constancy and Firmness of these Vessels in the Kidney is such as admits not of the like Variation.

§. 381. Therefore in a healthy State there is never any Humour voided through the Kidneys which is thicker, or so thick as the Blood, its Serum, Chyle, or Milk: and hence Waters<sup>2</sup>, especially the faline<sup>3</sup>, drank cold are diuretic; but fermented Liquors are the least diuretic, (§. 56.) and the less as they abound more with oily 4 Particles. But acid and thin Wines very soon pass off by Urine.

We cannot but reflect with some Remorfe upon the many Observations which have been made in the Practice of Physick, when we find most of them so inaccurate, that we can scarce confide in them, or build any thing with Reason upon them. I have frequently endeavoured to discover whether any of the Milk, Chyle, or Serum of the Blood itfelf was evacuated in the Urine in a healthy State. There are indeed fome Instances of polypous or grumous Blood having been discharged by the urinary Passages, of which Disorder perished one of the Professors of this University of Leyden; but these Grumes were derived from the Bladder, and not fecreted in the Kidney. I also find small Calculi larger than the Blood-globules floating in the Urine, but these are generally formed in the membranous Productions of the Kidneys, namely, in the Pelvis, Ureter and Bladder; for they were not fo large at the time of paffing through the cortical Substance of the Kidney itself. There are some Authors Au fwa but nat wh pai by ing

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Authors who tell us of a Grain of Barley being fwallowed, and afterwards evacuated by Urine: but in fuch a Case there must have been a preternatural Perforation or Dilatation of the Veffels, which collapsed again after the foreign Body had passed through. Thus I saw a leaden Bullet which by degrees made its way towards the Skin, appearing first under the Cuticle to the Touch, and afterwards making its own way through the Skin itself with so little Injury to it, that there seemed to be almost no Opening left behind: and in the fame manner Fragments of Bones make their way towards the Skin and are discharged out of the Body. But all these are extraordinary Instances, and not to be alledged as the Consequences of the natural Fabric of the Parts. We are likewise furnished with many Observations of Matter evacuated with the Urine upon the drying up of an Ulcer; but that Matter is not discharged in the thick and tenacious Condition in which it usually appears, but it is first highly attenuated, diluted, and again asfembled together after the Urine has stood some time in the Pot, so as by the Viscidity of its Parts to regain the Appearance of Pus or Matter. These Experiments therefore by no means prove that Humours as thick as laudable Matter pass through the renal Ducts; for if such a kind of Reasoning was to be admitted, one might eafily demonstrate, that a Cylinder of common Salt as thick as ones Finger passed through the renal Vessels: for certain we are that fuch a Cylinder may be dissolved in Water, drank, discharged in the Urine, and again crystalized into its former Bulk; and therefore Lumps of Salt are as well evacuated through the Kidneys, as the purulent Matter observed by these practical Writers.

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<sup>2</sup> Water is the best of all Diuretics, especially when its Force is increased by drinking it cold, and mixed with Salts; for if the Water be warm,

it rather inclines to fweating.

3 Salts that are alcaline both fixed and volatile, Sal Ammoniacum, the effential Salt, and Spirit of Urine, with cooling Salts, which do not incline to fweating, such as Nitre, Sea Salt, &c. To these add the recent Urine drank warm from a Cow, the Juice or Liquor of Oysters, or Muscles and Cockles diluted with Water, the Tartar of Wine, Vinegar and Water, which all cool and promote Urine. But Cantharides and Millepedes are not diuretic, but operate by inflaming the Bladder.

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4 Oily and sweet Wines, and such as the Spanish, with distilled inflammable Spirits, can neither be drank in large Quantities, nor readily discharged by Urine: but thin acid Wines are by Drinkers often swallowed to an immense Quantity, and they easily pass off by Urine with little or no Detri-

ment.

§. 382. From hence we are capable of refolving the Questions, from whence arise the Quantity 1, Colour 2, Smell 3, Taste 4, Consistence 5, and Contents 6 of the Urine, with what floats upon the Surface 7, is suspended in 8 the middle, or subsides 9 to the bottom of that Liquor? Namely, that these arise variously, according to the different Quantity of Water, Spirit, Oil, Salt and Earth entering into the Composition of the Urine, more or less intimately combined, according to the different Degree of Attrition which they have suffered in the Vessels. And this is more especially demonstrated beyond other things by the Phosphorus 10.

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A large Quantity of Urine is voided, when watery Liquors have been drank plentifully, and

the Kidneys likewise appear very compact.

<sup>2</sup> The Colour arises from the Fat combined with the Water by the Heat and Attrition of the circulating Blood; for pure Salt is always white: but Oil, though ever fo white, does by Heat and Attrition become rancid and yellow. If Bacon or Lard be fuspended in a warm Air, its white Colour changes into a yellow, and at the fame time acquires a rank Smell and Taste. The Colour of the Urine increases from that of a pale Straw, and according to the Velocity or Heat of the Blood, it passes through all the various Degrees of Redness even to a black, and then Death is either at the Door, or has actually taken Possession, as we are affured in the Plague, ardent Fevers, &c. But here it is to be observ'd, that the Intensity of the Colour does not arise from the Quantity of the Oil, but from the Degree of Corruption: for the most healthy Urine will barely by standing and putrefying become red, and even black, without at all increasing the Quantity of its Oil.

The Smell of the Urine arises from its Oil, as we observed before; for Salt being well cleansed from its Oil is inodorous: and in Distillations the saline Part of the Urine remains at the bottom, while those Parts which have the strongest Smell ascend together with the Water. But the seetid Smell of the Urine is increased in ardent Fevers from the Intensity of the Heat: for nothing putresses sooner than Oils, and stinking Smells arise only from the Oils turning alcaline. Therefore by separating the Oil from the Urine, it will be de-

prived of its Smell.

Its Taste is very peculiar, nauseous, sulphureous, bitterish, subputrid, and in most acute Discases cadaverous.

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Its Thickness or Consistence arises from the Oil, Salt, and Earth conjunctly; for Water is thinner than these, and Spirits, if there be any in the Urine, are still thinner than Water. fore the Confiftence of the Urine is in proportion to the Quantity of Water inversly, increasing as the Quantity of Water is diffipated or diminished: and from the same Cause likewise the Smell, Colour and Saltness will be also increased or diminished with the Thickness of the Urine. But the greatest Consistence of the Urine is derived from the Earth, or the folid Stamina, which have been abraded by the circulating Humours from the smallest Fibres and Vessels of the Body: and of this nature is the lateritious Sediment, which fubsides in the Urine after the Paroxysm of an intermitting Fever; and the like Matter is also depofited in the Scurvy, the most certain Sign of which may be deduced from this copious Sediment of the Hence therefore we may be capable of Urine: judging concerning the State and Condition of the Blood, from the Smell, Tafte, Colour, and Confiftence of the Urine, which if paler than ordinary, denotes a Diminution of the vital Powers; but if redder than usual, denotes that the Vis Vitæ is too intense.

6 The Contents of the Urine arise chiefly from the oily and earthy Particles combined; and to this Head belong the beneficial Sordes, which render the Urine of febrile Patients turbid. Even if you view it with a Microscope, you will see pyramidal Corpufcles, which are the true Matter of calculous Concretions.

What floats upon the Surface of the Urine in the Form of Clouds or Skins, arise from the Oil and most subtilized Earth so much attenuated as to be capable of swimming in Water. Their Dif-

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ference results from the Proportion of the Oil to the Earth, and from their more or less Lightness and intimate Mixture. The Nubeculæ or Clouds proceed chiefly from the muriatic Salt. The Dutch Sailors after returning from Afia, when they have lived for feveral Months only upon falted Provisions, and drank but little Water, they void a cloudy Urine, which Clouds being viewed with a Microscope appear to be Sea Salt.

8 The suspended Matters in the Urine are indeed mixed with Water, but are rather heavier of the two; and they differ from the former in containing more Earth, which is the Cause of their

being heavier.

9 The Hypoftafis or Sediment of the Urine refults from the falt Earth and fandy Particles. But to these we ought to add those Contents of the Urine, which adhere to the Sides in the Form of

Crystals or Tartar.

Phosphorus is a surprising Body, discover'd or invented by a German Chemist, named Kroft, and afterwards described by Kunkel, and is made in the following manner. Take a large Quantity of human Urine, as containing more Phosphorus than Blood, and expose it for a long time to Putrefaction; after which distil it to Driness in strong and close Vessels, till all the fluid Parts are drawn off, and what remains behind appears black and dry like a burned Coal. In the next place, let the Receiver be changed, and another adapted which. is full of Water, and let the Fire be increased throughout all the Degrees, till after a few Hours, and not before, the Phosphorus will begin to arise with a Fire, which is fufficient to make the Iron Retort glowing or white with Heat: thus will a bluish-colour'd Fume arise and pass into the Receiver almost like the Flame of burning Sulphy. L 3

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which will fink to the bottom of the Water, and run together in Flakes of a pale Blue, shining in the Dark, and in the open Air burfting into Flames; but which may be preferved many Years without burning, provided it is kept under Water, and well fecured from all Commerce with the Air. This is certainly a wonderful Instance of the Power exerted by Fire in changing Bodies. We have here a furprising Substance, which is neither Salt, Earth, Oil nor Spirit, but a new Substance or kind of Body very little known to us. It is not Oil, notwithstanding it dissolves in Oil; fince upon mixing it with boiling Water, it does not afford any Marks of Fatness; but as it disfolves in Oil and Alcohol, burns and fmells without mixing with Water, it may therefore be not improperly referred to the Class of oily or fulphureous Bodies.

§. 383. Also the Reason will be from hence evident, why bloody Urine 1 is often observed after violent Motion, or other Exercises, notwithstanding the Kidneys are sound, and there is no room to suspect a Calculus.

It is an Experiment of Peyerus, that if you inject Water heated to the hundredth Degree of the Thermometer into the renal Artery, and continue it for some time, the Kidney will then become extremely white; and if then you inject some coloured Liquor, it will pass together with the tinging Ingredients into the Pelvis and Ureter. It frequently happens, that healthy People of a reak Habit are surprised to find themselves of a sidden discharge bloody Urine, after they have ben carry'd swiftly over the Stones in a Cart or Waggon

Waggon to which they have not been accustom'd. I for a long time did not understand the Reason of this Phænomenon, which I had often observed: but at length I perceived the whole Affair in a learned Man, who understood the Make of his own Body. For after riding an uneasy Horse with great Expedition upon urgent Business, he found that upon his Return he made bloody Urine. Being thus affrighted, he made no doubt but that the Blood came from a Rupture of the Blood-vesfels in the Kidneys, and was therefore perfuading himself that he must have a very bad Stone: hereupon he confults a Physician, who from the same Theory orders Oil of Almonds, to abate the inflammatory Heat of the Kidneys, and mitigate the Afperities of the supposed Calculus. But the Patient foon after voids Urine with a Sediment very much like purulent Matter; whence he becomes more strongly confirmed in his Opinion of a Stone, when in reality the supposed Matter was pure Oil of Almonds. The Patient therefore making no doubt of a Calculus, calls another Physician (myfelf) who confidering the Hiftory of the Disease, and finding no Signs of a Calculus, plainly perceived that florid Blood without any Grumes had been forced through the Kidneys by the violent Exercise; and what he afterwards supposed, and called the Mucus of the Bladder, was no more than the Oil of Almonds; I therefore concluded from a Confideration of the Circumstances, that the Blood being put into a violent Motion by the Exercise, had dilated the uriniferous Ducts of the Kidneys, and passed through the Tubuli of Bellini, and that after this the Oil of Almonds had passed the same way; and therefore the Patient was cured in a few Days time merely by Rest and a thin Di-This Way of discharging Blood in the Urine 1 4

## Action of the Bladder. § 384.

often happens in acute Diseases, barely from the Continuity or opening of the renal Arteries into the uriniferous Ducts, as happens in most acute and pestilentious Fevers, the Small-Pox, Pleurefies, &c. in which it proves very fatal, infomuch that Sydenbam mentions only one who recovered after this Symptom in the Small-Pox during his Observation.

§. 384. From what has been faid also (§. 318 to 383,) an Answer may be given, whether a Separation of the Urine through the Kidneys is absolutely necessary for the Preservation of Health? or whether it may not be supplied by substituting other Excretions 1? and lastly, of what U/e 2 it is to the Body.

I am persuaded from many Observations that an intire Suppression of Urine must be mortal, and that the Patient cannot survive it above fifteen Days for the most part. Drelincourt having tied the Ureters in living Dogs and replaced the Intestines, turned the Animals loose and supplied them with Food, but yet they did not furvive it, I have tried feveral Methods in the most desperate Cases, and amongst others repeated Bleeding, which yet scarce retarded the Patient's Death for more than a few Days, at which we need not wonder: for if among fixty Pounds of Blood there are fix of Urine, the taking away of ten Pounds of Blood will still leave Urine enough behind to destroy the Patient. I have fometimes excited a Vomit twice a Day, and used Purges of Jalap, but without any Relief to the Patient. Acids indeed relieved them more, but neither could any of these save them: for some Days after the Begin-

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ning of the Disorder, they begin to imagine themfelves over Head and Ears in the Water, which is a Sign that the Brain begins to be overflowed with Serum; and after this the Breath and Sweat fmell of Urine, all the Senses are stupified, and the Disorder seems to be less troublesome, except perhaps the Terror which the Patient conceives from the Apprehension of his approaching Death. and at last the incurable Disorder passing through all the Degrees of Stupidity and Sleepiness, terminates in an Apoplexy and Death itself; and upon opening the Body, hardly any other Cause of Death can be found than a Quantity of fœtid Water filling the Ventricles of the Brain, that is some of the extravalated Urine. There was a certain Minister at the Hague charged with very important Negotiations, who through the Multiplicity of his Affairs neglected to make Water for a whole Day and Night, and upon endeavouring the next Day at Noon to discharge the Urine which he had so long retained, nothing could be evacuated. on the third Day a Catheter was introduced into the Bladder, but no Urine was evacuated; and on the fourteenth or fifteenth Day he expired. The Symptoms that attended were a Drowfiness on the fixth Day, followed with a Sleepiness, and dreams of being drowned, Breath and Sweat stinking, the Pulse increased, Convulsions, a Lethargy, and at last Death itself; and in the Ventricles of the Brain was found a Quantity of Urine.

<sup>2</sup> The Use of this Secretion is, 1. To free the Blood from its acrid and offensive Oil. 2. To cleanse the Blood from its stony or mineral Particles, which form Calculi in different Parts of the Body, if they are not washed out with the Urine. And besides that, to separate the Oil, which is become injurious by too great Attrition and Ran-

cidity,

## 154 Action of the Bladder. § 385.

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cidity, by which its Salts are too much inclined to be alcaline. But yet the Cause of the Patient's Death after a Suppression of the Urine, is not from an alcaline Disposition of the Blood or Urine; for if it was so, they might be preserved by a plentiful Use of Acids, which is contrary to Experience. I extracted a most feetid and acrid Urine from a Professor of this University, who died of an Ischuria; and to that Urine I poured Acids, but no Struggle or Effervescence followed. And therefore it is evident, that an alcaline Disposition does not arise in our Humours, but what their Acrimony will first considerably injure the Brain, and put a Period to Life.

But another Use of the Kidneys is to prevent the Formation of Calculi in the several Parts of the human Body: for the solid and earthy Stamina broke off from the Fibres are discharged with the Urine, so as to adhere to and obscure the purest Vessel, forming at length a Crust, and by degrees a Calculus, the Principles of which I have demonstrated to be the same with Bones, Horns,

Nails, &c.

§. 385. Since therefore the Motion 1 of the Humours, the Structure of the Body, with Ligatures 2, Injections 3, and ocular Inspection, joined with the Distempers 4 arising from a Suppression of the Urine, do very plainly teach us, that this Excrement can be only discharged conveniently by these ways from the Blood: there is therefore no Occasion to suppose or imagine Passages from the Stomach 5 and Intestines discharging Liquors from their Cavities into that of the Peritonæum; and then

then again to suppose corresponding Pores seated, as well in the Membrane which is extended over the Pelvis and Bladder, as also in the Bladder itself, by which Pores the Urine may be absorbed and conveyed directly into the Cavity of the Bladder; as also that there is no Obstacle to resist such a Course of the Urine, but that the Course is quite free and expeditious. Lastly, To suppose or invent the Appearances which such a Passage requires, when at the same time there are no Arguments which can be brought to prove the Passage itself.

The Urine flows last from the Urethra, which receives it from the Bladder, the Bladder from the Ureters, the Ureters from the Pelves, and the Pelves from the Papillæ; which Papillæ receive the Urine from the Tubuli of Bellini, and these last receive it from the small Arteries themselves, which are continued from the renal Arteries. So that from the first to the last, the Urine passes from the renal Arteries into the Urethra.

This Experiment has been frequently made by Drelincourt. He opened the Abdomen of a living Dog, taking care to prevent too great Injury from being offered to the Blood-vessels; and he then made a Ligature upon the Arteries: hereupon the Dog evacuated what Urine remained in his Bladder almost so entirely, that scarce a Drop remained, and some time after the Animal died lethargic; but upon opening the Bladder, it was sound persectly empty.

by the emulgent Artery, runs partly into the corresponding responding Vein, and Part of it penetrates into the

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uriniferous Ducts, Ureters, and Bladder.

4 Certain Death follows, when a Person has both Kidneys or both Ureters obstructed by a Calculus, or by any other Cause; and upon opening the Bodies of such Persons after Death, the Bladder

is found empty.

There have been at all Times, and in all Ages. certain Persons who have sought after a different Passage of the Urine from that which it takes through the Kidneys, which was believed too short a Course. There are Fibres described as pasfing from the Stomach to the Bladder, in Hippoerates's Book De locis in bomine, which we may perhaps interpret to be the Ureters, for any other Course appears to have been refuted by Erasistratus: but the Opinion was revived again some Years ago, and is at length almost expunged. About the Beginning of the present Century, it was proposed in the Memoirs of the Royal Academy of Sciences at Paris, that there were two kinds of Urine; one which is commonly fo called, containing the oily, faline, and earthy Parts of the Blood which are separated in the Kidneys; and another fort of Urine which is very thin and watery, paffing through new Pores or Ducts into the Bladder. This Opinion was proposed by its Author with so many feeming Advantages on its Side, that he hoped it would be univerfally allowed without Difficulty by all. It was therefore the Opinion of the learned Members of that Academy, that the Urine properly fo called, had a different Paffage from that which is commonly known into the Bladder, by whose Pores it was absorbed without first passing through the Kidneys. After reading the ample Demonstration of Morinus in the Memoirs of the Academy for 1701, I could not conceive

conceive any Conviction in it. His Reasoning feemed to be to the following Purpose: That all the Drink passes into the Stomach, but that a confiderable Part of it was absorbed through the Pores of the Stomach; and so far his Position is true enough. But it is then added, that the absorbed Liquor passes through the Pores of the Stomach into the Cavity of the Abdomen; whereas this is a false Proposition: for the absorbing Pores in the Stomach belong to the Veins; but the Veins do not exhale nor discharge any Liquor either out of the Body, nor into the Cavity of the Abdomen, but return their absorbed Liquors into the larger Veins, thence passing by them to the Heart, and from the Heart to the Arteries. It is then added, that the absorbed Liquor distilling like Dew through the Pores of the Stomach, is applied to the Surface of the Peritonæum, which lies next to the Bladder; and being again absorbed through the Pores of that Membrane, passes to the Bladder itfelf, by whose Pores also it is absorbed, and falls into its Cavity; and thus there is an immediate and ready Passage given to Liquors from the Stomach into the Bladder, without passing either into the Blood, or going through the Heart, Lungs, Arteries, and Kidneys. But no Person cou'd ever demonstrate, that the Water which is transfused into the Cavity of the Abdomen, is ever absorbed through the Pores of the Bladder, notwithstanding they make it one of their Arguments, that dropfical Patients have thus a ready Passage for evacuating the Water by diuretic Medicines. For when that Water is discharged by Urine, it returns through the Veins into the Blood. But if there was another Course for the Urine to pass into the Bladder, distinct from that of the Kidneys; what Reason can be given, why those Patients are killed,

led, who have a total Obstruction of both Kidneys, or both Ureters, either by an Inflammation or a Calculus. For in a Suppression of Urine arifing from these Causes, not a single Drop of Urine passes into the Bladder, nor out of the Body, except a few Drops of Mucus which arise from a different Quarter; and what is still more, the Bladder is usually found empty after the Death of fuch a Patient, which is feldom protracted beyond the fifteenth Day. But if the Bladder has absorbing Pores by which Urine can pass into it, as well as by the Ureters, why do we not find the Bladder filled in these Diseases by absorbing the Urine? But they proceed to confirm their Reasonings by Experiments; for, fay they, if the Stomach be either inverted or not, and the Pilorus is accurately tied, while its Capacity is filled with Water by the other Orifice; if the Stomach be then suspended, it will in a few Hours quite empty itself; and therefore they think it evident to a Demonstration, that there is a Passage in a dead Body from the Cavity of the Stomach through all its Membranes, by which Liquors may freely pass into the Cavity of the Abdomen. But this is a very great Fallacy; for when the Stomach is taken out of the Body, it is cut off from its Connection with all the other Viscera, from the Pancreas, Colon, Omentum, &c. In doing which the Veins are divided, namely, the Epiploic, Pyloric, Vafa brevia, &c. by which the Stomach communicates Therefore the Water which is with those Parts. absorbed by the bibulous Ducts of the Stomach, passes into the Trunks of these divided Veins, and flows out through them: but if those Veins were not divided, it would pass into the Mass of Blood. The last Experiment urged in favour of this new Course, is, that warm Water or mineral Waters

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are evacuated almost as soon as they are drank. But even this Observation has no Force in favour of their Hypothesis. For it is not that Water which is immediately drank, which passes into the Bladder, and urges the Patient to urine; but it is from the other old Water and Humours of the Blood being propelled and forced more swiftly through the Kidneys by the cold Water last drank. by which also the Bladder itself is urged to evacuate its Contents. Hence it is that never fo much Urine is evacuated, as there is Water drank, but always fomething less. If after drinking the first Draught, another Draught be again taken after a short Interval, the former will be expelled by the latter; fo that the first Draught will be expelled by the third, the fecond by the fourth, and fo on in fuch a manner, that what is last drank will never be expelled until there is an Accession of more. That this is the Course or Manner in which mineral Waters are voided is demonstrable, 1. Because the Urine which is discharged after drinking the first Draught in the Morning, whether hot or cold, appears by its Colour and Smell to be the concocted Urine of the Blood and Chyle, and not the Remains of the mineral Water. 2. Because the Urine which is voided after the fecond Draught. appears half concocted, paler than the former, but yet tinged with some Colour, and therefore neither is the Urine of the mineral Water voided at the fecond time. 3. The Urine which is voided in the next or third place, is the first that appears pale or watery, and by its Colour or Smell feems to be the Remains of the Water which was first drank. 4. All the Water which is drank is never entirely voided in an equal Quantity by Urine; but if ten Pints were drank, about eight of them will be thus evacuated; which is a manifest Indication,

Indication, that the Pint last drank is not immediately discharged, but is retained for some time in the Blood-vessels, which it in part fills; and there waits, till by a succeeding Draught it is in a manner urged, as it were, by Pressure in a continued Stream through a Tube.

§. 386. From hence also we may perhaps be able to determine, whether the Kidneys conduce any thing to the Formation of the Semen, and how far they conduce towards it? at least the Vicinity of the emulgent and spermatic Arteries, denotes some latent Sympathy betwixt these Parts.

It is a common Phrase among the ancient Hebrews with the Inhabitants of Asia, Arabia, and Syria, to speak of their Children and Kindred, as having descended in common from the Loins of their Grandfather: in favour of which Diction, we may alledge the constant Vicinity that is found betwixt the spermatic and emulgent Arteries, not only in Man but also in brute Animals; and the spermatic Vein on the left Side almost continually discharges itself into the emulgent Vein of the same Side. The feminal Veficles in all Animals are constantly fixed at the Neck of the Bladder, but yet this is no Foundation for the Reason alledged by Galen, namely, that the subputrid and saline Urine might mix with the Seed to produce the greater Titillation: for there is nothing putrid in the Semen, even though it has been retained for many Years in its Vesicles, but is always of a mild balfamic Nature. But I am afraid we can have but little Hopes of expecting any Light into this Affair, from the Discoveries of Valsalva.

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Swammer dam, Redi, and other Naturalists demonstrate, that all Fowls and Birds, and also Fish do evacuate Urine, though in a different Manner from Quadrupeds.

- §. 387. Lastly, it may also appear from what has been said, why Gravel and Stones are so frequently formed from the Urine, in its several Passages?
- It is demonstrated in another Place (§. 434.) that the human Body continues the fame but for a a very short time, its several Parts being continually changed, till at length the whole is renovated. The Nails or Hair being cut or shaved off at the usual times, are supplied with more of the same Kind; and even if a large Part of a broken Bone be taken out, so as to leave a considerable Space. the whole Cavity will be filled up in a few Months with a Substance nearly resembling that of the Bone itself, so that in three Months the Bone will be restored to its former Continuity. In Asia it has been customary for People through all Ages past, to let their Beards grow; and the Europeans who live there being accustomed before to shave their Beards very close, are nevertheless furnished in about fix Months time with a Beard as long as the rest; nor will it grow to any greater Length, even though it be continued for a longer time; and therefore those who have continued their Beards for many Years, have them by degrees changed by the Production of new Hairs. fee that all the hard and foft Parts of a Chicken are produced in the Space of twenty-four Days, from the fluctuating white of an Egg: and even Man himself arises from an insensible Drop of the feminal Fluid. From all this it is evident, that all

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the folid Parts of the Body which have performed their proper Offices, are continually abraded and confumed, while at the same time there is a perpetual Renovation or Restitution made of new Matter to supply the Place of the old; and this properly is the Nutrition of an adult Perfon, namely, for the folid Parts to be supplied with as much Matter from the Humours, as is daily wasted and cast off from the Body: so that every solid Part of the human Body which has performed its Office, is continually evacuated or cast off; but whether or no these Exuviæ become first acrid, I cannot determine. But these solid Staminæ or earthy Particles of the Body can neither be difcharged by the Intestines, nor by the Skin in the Form of perspirable Vapours or Sweat, and therefore it follows, that they must be deposited in the Kidneys, and evacuated together with the Urine; fo that a Retention of them in the Kidneys will produce a Stone. But that the Kidneys only are the proper Outlets for these excrementitious folid Particles, may be eafily demonstrated by Experiment. For if you take Urine as it flows warm from the Body into capillary Glass Tubes, and view it with a Microscope in the Rays of the Sun, it will at first appear pellucid, till at length it will continually deposit little Scales, which are the true constituent Particles of a Calculus, and will in a little time fix themselves to the Sides of the Glass Tube. Thus we also see a stony Crust of the same Nature formed about the Sides and Bottoms of Chamber-pots; which Crust is at first very thin, but increases by new Strata, which if not scoured off, while more Urine is continually poured into the same Vessel, it increases sometimes to fuch a degree, as totally to cover the internal Surface of the Glass or Receptacle in which it stood.

If these Particles are not continually washed out of the Body, but fix themselves in any Part, they form a Magnet, to which the similar stony Particles will adhere, and from hence will arise a Cal-Even in any Part of the Body, not excepting the Brain and Tefficles, a Calculus will be formed if there is but the least solid Particle to which that fabulous Matter may adhere, which ought to be deposited in the Urine: but a human Calculus appears to be a hard friable Body, diffolvable in no Liquor as hitherto discovered, except Spirit of Nitre. We know by Experience that a Magnet or Basis may be formed for the Adhefion of these sabulous Particles of a small Grume of Blood, Matter, a Bit of Wool, a little Membrane, a Splinter of Wood, a Fragment of Glass, or Lead, or a Particle of any other kind of a folid Body. A leaden Bullet which was shot from a Gun into the Bladder, continued there for a considerable time without giving the Patient any great Uneafiness, nor did he complain of the Strangury for a long time afterwards; but after the Person's Decease, a large Stone was found in the Bladder formed round the leaden Bullet. Nucke opened the Bladder of a living Dog, and inferted a little Ball of Wood; the Animal was afterwards cured of his Wound: but when that Anatomist cut open his Abdomen some Months afterwards, he found a Stone formed round the wooden Spherule. Tent flipping into the Bladder out of the Urethra by some Accident has been observed to lay the Bafis of a large Stone. If a Person does not use Exercise, while at the same time the uriniferous Ducts are compressed with too great a Load of Fat, the Passage of the Urine to the Bladder will be impeded, and the mealy Dust or scabulous Particles of the Stone will continually stop in the Tubuli Bellini-M 2

Belliniani, whence a Calculus will be formed. The chief Preservative therefore against the Stone. will confift in keeping the urinary Passages continually clear, and free from any folid Particles to which the Matter of a Calculus may adhere: in order to which two things are to be avoided, namely, 1. Never to lie for a confiderable time quite flat upon the Back. 2. Never to retain the Urine too long. But in the Beginning of the Diforder, while the Gravel is fmall and moveable. the best Method of relieving the Patient will be, by ordering him to drink a quarter of a Pint of warm Water before Meals, and to use moderate Exercise for about the Space of an Hour. Upon this Subject Fernelius, (Pathol, lib. vi. cap. 12.) deserves to be consulted, who is the first Physician that has wrote with Truth concerning the Calculus.

<sup>2</sup> The human Calculus is neither Salt nor Spirit, as Helmont imagined, nor is it Oil; but it is mostly fixed or permanent Air combined with the earthy Particles, which have been rubbed off from the smallest Vessels by the Force of the circulating Humours, intermixed and cemented together by fome of the urinous Salts and Oils, fo as to form

a compact or folid Body.

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Concerning the Structure and Action of the Muscles.

§. 388. A FTER having surveyed what Actions are performed by the Blood in its Passage through the Viscera, it will be necessary for us in the next place to examine

examine what it performs in paffing through all the Muscles 1 of the Body, and then to enquire into the Action 2 of the Blood, which is moved through the internal or external Integuments which invest either the Surface or internal Cavities of the Body.

A Muscle is by the Greeks said to be a Portion of Flesh resembling a Mouse, that is, having a peacked Head, almost without any perceptible Neck, joined to a pretty long and round Body, and terminating in a long slender and round Tail or Tendon. By a Muscle we mean an organical Part of the Body, capable of exciting, determining, or directing, and continuing the feveral Motions of all the Parts, at the Pleasure of the Mind. And this Definition explains not the Nature but the proper and characteristic Action of a Muscle. I am by no means pleased with the Definition which Philosophers give of Things, by intermixing their Natures or Descriptions; as for instance, in defining Gold, to give us an Assemblage of all the Ideas composing that Metal. If Philosophers demand fuch Definitions from Anatomists, it is more than we are capable of. But in my Judgment, a Body is rightly defined by affigning any one of its Characters, which are to be found in that and in no other Body: thus, for Example, Glass is a pellucid Body, brittle in the Cold, and formed of flint Stones or flinty Sand, combined with an alcaline Salt by the Force of Fire. This Character of Glass though it does not expound its Nature, is certainly fufficient to diffinguish it or prevent it from from being confounded with all other Bodies. In the same manner we define a Muscle; for there is no Part muscular but what M 3 is is productive of animal Motion; and if you except against the Definition, that there are some Muscles whose Actions are not governed by the Influence of the Will; I answer, that they are nevertheless of the same Fabric with those Muscles which are the Servants to execute the Inclinations of the Mind.

We are in this Place therefore to examine in what manner the Muscles follow the Influence of the Will: namely, as if a Person is walking with a quiet Mind, and thinks that after a hundred Steps he will have his right Hand held by his left, in a prone Situation; it is manifest that such a Motion will proceed entirely from the Will. In order to explain this Motion, it cannot be supposed necesfary to affign the Manner of its first determinating Cause; for this is not only out of human Capacity, but would be equally useless as it is impossible, If I am about to explain the Motion of a certain Ball marked A, and demonstrate that it is moved by another Ball marked B, I shall have then performed the Task without enquiring from whence the Ball B derived its Motion. Again, for Instance: I see a Person in Health compose himself to Rest in his Bed, and when he awakes in the Morning, he endeavours to draw the Curtain: but fuch a Person is then surprised to find that his Hand does not obey the Motion, which he inclined to perform; and it is the Cause of this Motion which the Hand possessed the Day before, but of which it is now destitute, that we shall take upon us to explain,

§. 389. But this being one of the most difficult and obscure Subjects, as being seated in the most minute! Vessels and Instruments? of the Opinions, and has at the same time render'd

it difficult to chuse the best.

The smallest sanguiferous Vessels are scarce vifible by the Microscope; but the Vessels of which we here speak may be some Myriads of times less than these: but notwithstanding the Aspect of so great a Difficulty, the human Mind, being impatient of Ignorance, has contrived various Methods by which this Motion may be brought about, infomuch as to render it difficult to judge berwixt the contrary Doctrines of the Learned. But in general we are to observe this, that if a hundred are of different Opinions, there may be some Truth in each of them, as well as some Fallacy, nor was any Proposition ever started so perfect as to be without Defect. But if we collect together out of each System every thing which appears to be true, and join them into one, we shall then

have an Edifice moderately perfect.

<sup>2</sup> In other Parts of the Body, the Microscope and Injections affift us in determining their Structure; but in this Case both these Artifices are but of little Service to us. But it is first necessary to obtain a Knowledge of the Figure of any Instrument, in order to explain its Use, otherwise we must always despair of being satisfied that our Explanation is true. If you fay an Instrument is Iron or Steel, you fay nothing towards explaining its Use; but if you say an edged Instrument of Steel is ground into a Razor, you may be then capable of applying it to mechanical Principles, fo as to explain the Power and Action of the known Antiquity, it must be confessed, has left us no Affistance in this Affair; for all our Knowledge in this respect is owing to the Mo-M 4 derns. derns, who perceived the Actions of the Muscles without being able to discover their Fabric, and for that Reason they have been always instable, or wandering in their Opinions.

§. 390. But to proceed; the folid Parts of the human Body are either moved by the Impulse 1 of the Humours 2 which flow forcibly through them; or else they are moved by means of Muscles 3 which are fasten'd to the Parts destin'd for Motion: but this last Kind of Motion ceases, when the Muscle is either divided, broke asunder, or corrupted; and this Motion is either voluntary 4, spontaneous, or mixed.

The Aorta receives two Ounces of Blood from the Heart in a fecond of time, and expels as much through the Vessels in the same Instant of time: and therefore the Motion of the Blood appears to be strong and rapid; for the Strength of this Motion is evident from the Heat refulting from that and the Attrition, fince when the Motion of the Heart is removed, the Parts immediately become cold. But all this Attrition and Heat refults from the Force and solid Fabric of the Artery; for the most fierce Horse who soams with his Strength may be eafily quieted in a few Minutes time without at all changing the Humours, but only by running him under Water, by which the Motion of the Heart and Arteries will be removed: and therefore this muscular Strength did not reside in the Fluids, but only in the folid Parts.

Both the vital and the animal Fluids each of them concur to this Action: for when once the Motion of the Blood and Spirits through the

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Nerves is suppressed, all the Power of the Solids

is immediately destroyed.

In order to point out any Object with the Forefinger, the Tendon of it is immediately extended, as one may plainly perceive, towards the Wrist: but if the Muscle does not act, the Finger will not be extended, and therefore the Motion of

the Finger is from the Muscle.

- For Example: Suppose the Influence of the Mind destroyed, which is necessary to produce the Motion of a Muscle, as we find it is in a paralytic Patient, there will nevertheless be no visible Alteration apparent in the paralytic Limb; but yet he will not be capable of moving that Limb at pleasure, which is therefore from a Desect in the Muscles. But this voluntary Motion of a Muscle is very different from the natural Motion of its Fibres, which always endeavour to contract themselves; for that contractile Force still remains in the paralytic Limb, and even increases after Death, when all the Motions of the Muscles are destroyed.
- §. 391. All Muscles are said to act, when, being render'd shorter 1, they draw together, or press the solid Parts to which they are attach'd, or expel the Humours by their Pressure.
- That the whole Action of a Muscle consists in this Contraction or Shortening, will be readily allowed by every one who has made the least Observation of them, or who has but the least Skill in anatomical Matters: for when the lower Jaw is relaxed, or let down, the Massetr Muscle may be easily felt with the Hand; and in biting, it may be perceived to shorten and swell. Even when you move

move any Part of the Body, as the Arm, all that you have done is the shortening of those Muscles which move the Arm; and the Length, which is taken from the natural Length of the Muscles in their shortening, is the exact Measure of the Motion of the Arm. But though there is another Class of Muscles, which either contain or carry some Humour; yet there is no Difference in their Motion, for they are likewise contracted about their contained Humours, which they expel by that Contraction. Of this nature are the Heart, Intestines, Bladder, Stomach, and Arteries: for these have a Contraction in the living Animal different from that which they continue to exert after the Animal is dead.

- §. 392. All the Difficulty therefore in this Case is to assign the Fabric 1 and contracting Cause of the Muscle; one of which must certainly have a great Dependance on the other.
- If we have but once an Idea of the Fabric of the Parts of the human Body, we have then also an Idea of all its Motions: for the most inquisitive Physician does not fearch after the most remote Causes, but those only which are capable of being immediately perceived by our Senses. And he who has explained the proximate Cause, must be allowed to have given the whole Account. Instance; the Body A strikes upon the Body B, which was before at Rest; I say, that the moving Body A is the proximate Cause in the Motion of the Body B, which is all that we enquire after. For by a Cause we understand a Being related to fome Effect, which Cause being removed, the other relative Being, which we call the Effect, is also removed, and the Reverse. What Person, in order

order to explain the Action of a Razor, would take upon him an Enquiry, after the Manner in which the Steel or Iron was generated in the Earth, and in what Manner its component Particles were differently combined and figured? Certainly such a Person would spend more than a short Life in an useless and tedious Enquiry after a Chain of Caufes and Effects.

- §. 393. Every simple Muscle hitherto known confifts only of one fleshy Belly and one Tendon, and may be again divided into other smaller Muscles perfectly like itself, excepting the Difference of their Size; and even these smaller ones which compound the larger, may be again divided into still less, plainly alike in all respects but in Magnitude; and indeed this Division proceeds so far, that at last they become so incredibly small, as to exceed all the Power of Imagination. But Reason tells us that there must be an End. Since then the last and smallest is like 2 the whole Muscle, it must needs have its Belly and Tendon in the same manner as the larger, but must be called a muscular Fibre, by an Affemblage of which is formed a Muscle properly fo called.
- Lower was the first Anatomist who opposed the ancient Opinion, which attributed but one Belly, one Head, and one Tail to every single Muscle, that is to say, two Tendons, and one sleshy Belly. But he demonstrated that every Tendon had its proper muscular Flesh, and that therefore two Tendons had likewise two sleshy Bellies in the

Sphincters.

the same Muscle. But in most Muscles one Tendon is fixed to an immoveable Bone, and this is called the Head of the Muscle; while the other Tendon, which is inferted into the Part to be moved, is called its Tail. Indeed fome Muscles are excepted which have no fixed Point, such as the And the Moderns divide other Muscles into much smaller Portions, each of which is furnished with its fleshy Belly and Tendon; and of this nature there may be near a dozen distinct Por-

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tions observed in the deltoide Muscle, which Ruyleb has even separated into thirty Muscles. But even here the Division does not terminate, but may be carry'd still further; infomuch that the whole deltoide Muscle may be truly said to consist of one hundred and forty-four small Muscles, each of which has its diffinct Tendon: for the Tendon of

any Muscle may be divided by Maceration into as many Parts as its fleshy Belly, as the Experiment may be very well tried in the large pectoral Muscle. But the temporal Muscle is almost simple

below, whereas above it is divided into above fifty Tendons. The Biceps of the Cubitus, and the Triceps of the Thigh, are very diffinct Muscles, which meet together in one Tendon; but they

have as many diffinct moving Causes, as they have Lewenboec has at length also distinct Muscles. applied himself to examine into the Muscles with his excellent Microscopes; and demonstrates, that one fingle muscular Fibre splits into numberless

other Fibrils barely by macerating in Water; and that one of those Fibrils, which to the naked Eye appears to be fimple and uncompounded, does ne-

vertheless by the Microscope appear to contain as many smaller Fibrils as the whole Muscle itself did contain of the visible Fibres, which appeared to be

the smallest to the naked Eye. In the vast Muscle

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of a Whale he separated the Flesh into Portions. these Portions into Bundles, and these last into Fibres, till he came to a fingle capillary Fibre; and this last Fibre he found to be as it were a Compendium of the larger Muscle, seeming as large, and made up of as many smaller Fibres to the Microscope, as there seemed to be visible Fibres in the large Muscle. But from the largest of Animals he descended to the smallest, and observed that the Foot of a Flea was contained in a fort of Case or Shell like that of a Tortoife, which being broke. the Muscle started out which was the Author of so great a Motion, and which, though feemingly but one Fibre, could be nevertheless divided by a very small Needle into lesser Fibres, each of which contained numberless other Fibres, remaining equally divisible with those in the Muscle of the large Grampus Whale, which weighed fo many Pounds.

2 Geometricians tell us, that fimilar Figures may differ in Magnitude, but have equal Sides and Angles proportionable to each other; from whence we may conclude one of the least muscular Fibres. which we are capable of difcerning, to be perfectly like the large Muscle itself: for we always find a fort of fleshy Belly tumifying in the middle, and growing small towards the Ends into little Tendons. In the Muscle of the fighting Cock which ftrikes the Spur, whose Tendon offifies, Lewenboec observed many distinct smaller Muscles into which he divided the large one, till they were at length as small as a Hair of one's Head; and then again by dividing that Fibre under the Microscope with a fine Needle, lacerating the cellular Membrane, by which they are connected together, he then found that one of the smallest Fibrils, which was no larger than the hundredth Part of a Hair, had exactly the same Appearance with those conspicu-

# 174 Action of the Muscles. § 394.

ous to the naked Eye. Hence therefore we may take it for a general and certain Rule, that the Action of a Muscle is the aggregate Sum of the Actions of the feveral fmaller Muscles of which it is composed.

§. 394. From what has been faid therefore it is evident, that these Fibres (\$ 393.) are neither arterial 1, venal, nor even lymphatic Vessels, but of a very different Nature; being Organs much more minute than those. Query, Whether they are vesicular 2, composed of a Chain of Bladders? or whether they are not formed in one continued Tract?

The Fibres of the Muscles could not have been well formed of Arteries of any of the Orders, even the remotest from the sanguiferous Vessels; since all the Arteries receive an uniform Motion from the equable and common Action of the Heart: and therefore upon this Principle all the Muscles would have been subject to the same Motions in all Parts of the Body at the same time. Besides this, they cannot be formed of the Veins corresponding to any fuch Arteries, fince their Minuteness exclude the red Globules of the Blood conspicuous in these Fibres.

Many of the modern Anatomists affirm, that the muscular Fibres are composed of Bladders; which Notion they feem to have imbibed from the Contraction of muscular Fibres by which they grow thicker: for every Fibre left to itself spontaneously contracts with a certain Force, as all other Bodies do by a certain degree of Cold, by which Contraction the Fibre is corrugated into a less Space. But it is not only a Property of the Fibres, but likewife

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likewise of all other Bodies to expand with Heat and to contract with Cold, which Appearances I have reduced to geometrical Calculation in the most compact Metals. It must be also observed, that all the longer Muscles in the Body are divided into less by Innervations or tendinous Intersections, as we see in the recti Muscles of the Abdomen: for without this Mechanism the animal Juices must have been impelled with an infinite Force to inflate or cause such a Muscle to contract. The like Intersections are likewise visible in the smaller muscular Portions as well as in the Muscle itself, and also in each small Fibre as far as our Senses are capable of extending; there are also many minute Fibrils interposed betwixt the Tendons which unite into one larger Fibre, and which feem to be a Sort of Bridles or Sphincters to confine the Fibre about which they are placed, but that this is their proper Action does not yet appear. By this means the muscular Intersections being contracted, produce the Phænomenon of Cowper, namely, a Corrugation of the whole Muscle into unequal Surfaces or Wrinkles like Bladders: but yet neither Cowper nor any one else could ever demonstrate real Bladders in the Muscles, notwithstanding he by injecting the Arteries with Mercury, found it pass into the Cells of the vesicular Membrane, which invests all the muscular Fibres; and the only Vessels which he could fill affording any Appearance of Veficles, were the lymphatic Veins which contain Valves.

§. 395. Since therefore the Nerves which enter every Muscle<sup>1</sup>, together with the Arteries and Veins, are judged<sup>2</sup> to deposit their external Coat<sup>3</sup>, (§. 281, 282.) and to be then distributed through the whole Body of the Muscle

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in fuch a manner, that there is no affignable Point in which there is not some Part of a Nerve to be found: and as thus all the Nerves vanish in the Muscles; whereas in other Parts of the Body, the Extremities of the Nerves being as it were expanded form Membranes; (§. 283.) from thence we conclude 4, having a regard to the Nature of the smallest Nerves, (§. 274.) that these Fibres 5 (§. 393, 394.) are a very fine Expansion 6 of the ultimate Extremities of the smallest Nerves, deprived of their Coats, hollow internally, and of the same Figure with the Muscle (§. 393.), being filled with Spirits or nervous Juice, (§. 275, 276, 277, 291.) which Juice is derived into the Nerve from its Origin or Fountain the Brain and Cerebellum, by the continual Force of the Heart.

In the Heart itself, which is a very strong Muscle, free on all Sides, and only continuous to its Sacculus the Pericardium, we may eafily perceive what Parts enter into the Heart, from whence we may derive the Origin of its Fibres and the Caufes of its Motion. But there are four large Veffels, namely, the coronary Arteries or Veins, Fat, and cardiac Nerves: now if (according to §. 394.) from the former of these there are no muscular Fibres arise, it will follow, that they must come from the Nerve, as will be more evident by the Reasons offered at (§. 400 and 402.) nor is it any Objection that the Nerve is incredibly smaller than the Muscle: for if we regard the true Bulk of the Muscle itself, as consisting of mere Fibres, it is extremely small; insomuch that if all the Humours, Vesfels. fels, and Fat are removed, there will but a very small Portion of fleshy Fibres remain, as Dr. Keil has very well demonstrated in treating on the Quantity of the Blood and Humours in the Body.

If you strip the whole Artery, Vein, and Fat from the Muscle, what remains seems to be the For when a Nerve enters a Muscle it never comes out again, but is fpent in the Muscle itself in which it disappears: nor is there any vifible Point of a Muscle which is not both sensible and contractile or moveable. If you prick any Part of a Muscle with the finest Needle in a From or any other Animal while living, it will tremble and be contracted, and even when the Muscle is cut out it will also contract by irritating its Nerve with the same Needle, as hath been observed by the diligent Naturalist Swammerdam: and therefore in every visible Point of the Muscle there is some Part of the Nerve, but the Arteries pass out of the Muscle and are reflected back in the Veins.

3 Every Nerve is covered with a Membrane at its Entrance into a Muscle, which Membrane is either derived to it from the dura Mater, or from fome Ganglion, either proper to itself, or common to several other Nerves. For since the essential Part of the Nerve which constitutes the proper Substance of it, is foft and like a Pulp, it was neceffary it should be secured and defended in its Course through the various Parts of the Body, by being covered with hard and refifting Integuments or Cases, which they throw off when they come to that Part of the Body where those Integuments are no longer wanted, that is, where the pulpy Substance of the Nerve itself is immediately to perform its Office. Thus the Integuments of the dura and pia Mater are continued with the Thalami of the optic optic Nerves, or anterior Productions of the Medulla oblongata, which are extremely foft and fluctuating like a Pulp: but when they are continued into the optic Nerve, they are so firmly secured by the Meninges, that they form a very hard Body or Nerve, which at entering the Eye deposits or throws off its external Integument derived from the dura Mater, which forms the Sclerotica of the Eye; and then the internal Integument derived from the pia Mater is immediately after expanded within the former, conftituting the Tunica Choroides, from whence arises the Tunica Ruyschiana. After the Nerve has thus deposited its three Integuments, it becomes a Pulp which is expanded in the Form of a reticular Membrane called the Retina, and ferves for the immediate Organ of Vision to receive the Impulses of the Rays of Light, and transmit them to the Sensorium. What has been here faid of the optic Nerve takes place in the Nerve of every Muscle throughout the Body, as far as we can perceive; for the Nerves of the Muscles spread their external Integument upon the whole Muscle itself, while their internal Integument, together with their external, are fuccessively ! continued to all the smaller Fibres in the same manner, whose Origin from the Nerve we are not capable of demonstrating to the Eye by reason of their Minuteness. Thus from the Distribution of the Nerve and its Integuments in this manner, are formed the Fibres which make the larger Part of each Muscle.

Diffection of all the cutaneous Nerves, which yet has been happily executed by the Industry of Enfactius, as we may readily perceive by the twenty-first and twenty-third of his excellent Tables. Vieusens, in his incomparable Neurographia, has

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also descended very minutely to the Termination of the internal Nerves, as well as those of the Skin. But Malpighi demonstrates, that the cutaneous Nerves being continued through the adipofe Membrane, at last terminate in the Skin itself, where they are interwove with the Arteries and Veins in the manner of Leather; but at length their Extremities deposit the hard Coat derived from the dura Mater, which ferves chiefly to compose the Cuticle, under which the internal Coat of the cutaneous Nerves, derived from the pia Mater, is immediately expanded in the foft reticular Body of Malpighi, which is perforated by the pulpy Heads of the Papillæ, which are formed by the proper Substance of the Nerve itself for the Sense of Touch. The Nerves of the ninth Pair terminate after this manner in the Papillæ of the Tongue. The Auditory Nerve is entirely changed into a foft mucous Membrane, which is spent in the Labyrinth and double spiral Canal. And therefore the ultimate Extremities of the Nerves in all Parts of the Body seem to be after the manner of a soft Membrane. But what we fee fo constantly obferved by Nature in those Parts which come under the Inspection of the Eye, the same we may also reasonably conjecture to take place in those Parts which are invifible.

The Smallness of these Fibres exceed all Belief. Lewenboec's Microscope so magnified a single Hair of the Head, that it seemed to be above an Inch Diameter; but even five hundred Hairs placed by the Side of each other, will not appear to the naked Eye to be of an Inch Diameter: and yet by the same Microscope, one of the smallest Fibres of a Muscle did not appear larger than a fingle Hair does to the naked Eye; and therefore it was not above one five hundredth Part as large

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as a Hair of the Head. But even here does not the Smallness of the muscular Fibre terminate; for though it cannot be any further divided, yet it appears to be made up of innumerable smaller Fibres in the same manner as the Muscle itself appears. Nor is it improbable, that if the armed Eye of Lewenboec was a thousand times sharper, yet the same Observation would be continued, namely, the continual Division of each Fibre into lesser ones. For that the Sense of Vision is not capable of penetrating to the ultimate Fibres, may appear, inalmuch as that Fibre is the immediate Organ of the Motion itself.

A small hollow Cylinder flatten'd into a Bladder, affords a very convenient Idea to explain the Distribution of a Nerve terminating in the ultimate Fibres of a Muscle: But this Fabric is no more than probable, fince it cannot be demonstrated to Sense any farther than it appears agreeable by Reason to the Uses affign'd for it. But this in general is true, that every thing which either perceives or moves in the Muscle, belongs only to the Nerve: and therefore every Muscle, so far as it is an Organ of Motion, appears to be a Continuation of the Brain, Cerebellum, and spinal Marrow; and that there is a continual Flux of nervous Juice from those Springs, namely, the Brain, Cerebellum, and spinal Marrow, into every Point moving the Muscle. But the Principle of Sense and Motion in the Muscles, regulated or governed by the Influence of the Mind, appears to be derived from the Brain; while the Principle of vital Motion, which is not voluntary, refults from the Cerebellum; and from the spinal Marrow again arise Nerves both for voluntary Motion and Senfation. Thus therefore there are Nerves derived from the Brain to the voluntary Muscles, and from from the Cerebellum to the vital or involuntary Muscles; as the Fabric of the Arteries, Veins, Membranes and Fat in the Muscle, do not derive their Motion from themselves, but from the Nerve only.

- §. 396. Of these smaller Fibres united together are composed Bundles, which again have another distinct. Membrane by which they are invested and distinguished, or separated from the other Bundles of the like Size; which holds true as far as the Senses can penetrate: but this distinguishing and connecting Membrane of the Fibres is cellular, replenished internally with Oil, which is accumulated in quiescent Animals, and consumed by Exercise, serving to anoint, defend, and lubricate the Fibres; and that this Fat or Oil is supplied from the Arteries into these Cells, is evident from the Injection of Mercury, which finds a ready Passage the same way.
- tegument or Capfule of the cellular Membrane, by which it is distinguished from the other Muscles, and adapted to contract or move itself freely. Thus the Heart is included in the Pericardium, and the other Muscles are each invested with their proper cellular Membrane, that the Skin might move freely over the Muscles, and that the Muscles themselves might move freely over those Parts which are placed beneath them. For if we cut through any Part of the human Body, the Order in which the Parts appear will be first the Cuticle, the reticular Body, the Skin itself, the adipose N 3 Membrane,

Membrane, and next to that the Muscles or their Tendons for moving every Part of the Body. Even the Cause of a free Motion of a Muscle depends in a great measure upon the adipose Membrane with which it is on all Sides invested: for in the same manner as the Panniculus adipofus is expanded under the Skin throughout the Body, so it also invests every particular Muscle, and even every individual Fasciculus of its muscular Fibres, of which there are great Numbers; as, for Instance, in the dethoide Pectoral and glutei Muscles. Lastly, It farther extends betwixt every individual or fingle Fibre of which the Facciculi are composed, of which fingle Fibres there may perhaps be some Myriads entering the Composition of a large muscular Fibre, which is visible to the naked Eye; and thus largely is the cellular Membrane expanded about every Fibre and Vessel, as appears from the Observations of Lewenboec. That curious Gentleman cut off a small Portion of the Muscle of an Ox which had been dried in the Smoke, and placed it under the Microscope; and he found that it refembled Windows of yellow Fat, betwixt which there were some of the red muscular Flesh interposed. If you inspect the Muscles of a Hog before fattening, they will appear quite red, with little or no Fat; but if the Muscles of the same Hog are examined about Autumn, against which time they are fed, it will be twenty times as large as before, and exhibit but very few red Fibres, betwixt which will be interposed little Bags full of Lard, infomuch that nineteen Parts out of twenty in the Muscle are made up by the cellular or fat Membrane. But this Oil serves, first, to render the Fibres flexible and eafily susceptible of their Contractions and Dilatations. 2. It prevents one Fibre from growing to the other, and hinders the Muscle

Muscle itself from adhering to the adjacent Parts. 3. It abates the violent Heat and Attrition of the Blood, and prevents its Acrimony; infomuch that there is no Fat but in Parts where some Attrition is to be taken off, or fome Acrimony mitigated: The more frequently any Muscle is put in Action, the more Fat is it usually cloathed with; as, for Instance, in the Glutei, abdominal and pectoral Muscles. If this Fat, which invests and diftinguishes each Muscle, and the several Parts of the fam. Muscle, be confumed or destroyed by Suppuration, the Motion of the Part is then destroyed, while the Flesh of the Muscle itself is not touched. Thus, after Abscesses, when the Fat has been confumed which separated the Muscles from the Skin and adjacent Parts, they will all cohere together, fo as to destroy the Motion of the Part, or make This I have experienced in myself, by burning my Thumb in making some chymical Experiment; for the Skin adhering to the adjacent Muscles, occasioned a Rigidity or Stiffness in the Motion, notwithstanding the Wound was perfectly cured; nor can I get rid of it by the Use of any\_Fomentations.

§. 397. But an Artery 1 is also distributed through every Muscle, in which its Branches are found fo large, numerous, and interwove in such a manner, that a Person who is not cautious 2 would judge the whole Body of the Muscle to be composed of that Vessel only. These Arteries are distributed chiefly betwixt the Fasciculi of Fibres (§. 396.), and in the Membranes which distinguish them from each other, and perhaps also upon the external Surface

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face of every individual Fibril (§. 393.); in which Places they terminate in reticular Plexus's, fecretory Oil Ducts (§. 396.), small or lymphatic Arteries, and perhaps into hollow Fibres like 3 Nerves; and these last hollow Fibrils may also terminate either in the hollow muscular Fibres derived from the Nerve (§. 393, 394.), or else they may themselves constitute Fibres of the like nature.

\* Eustachius has very well expressed these Arteries in his Figures of the twenty-fifth and twenty-fixth Table. But they are usually distributed through the Muscle in such a manner, as to run according to the Course of the Fibres. These Arteries are very large in the Muscles of the Abdomen, and there are not inconsiderable ones even in the Tendons themselves.

2 Ruysch happily injected the coronary Arteries fo far that an unwary Person might be easily perfuaded that almost the whole Heart was a Heap of Arteries: but in this Preparation Part is destroyed, and Part of the vascular System remains unfilled, especially by Maceration, in which those Vessels are diffolved where the Injection has not penetrated; while others of the Vessels are compressed, so that by the Expansion of those which are injected, the empty Cells, Nerves, &c. are obscured. But these Arteries are distributed also in part upon the Cells of the adipose Membrane for the Separation of the Fat; and perhaps they may be also diffributed in the same manner upon the ultimate small Cells or Cylinders of the nervous Fibres themselves. But it feems reasonable, that as a sufficient Quantity of Arteries enters the Muscle to compose the arterial System, and considerably increases the Bulk of that Organ; fo the Nerve expands itself into as many Branches as are necessary to compose the nervous System of the same Muscle. If we examine the Heart when its coronary Arteries are injected, as also the cardiac Nerves in their Diftribution through the same Muscle, we shall perhaps reasonably conclude, that there is no great Disparity betwixt the numerous Ramifications of each, conspiring perhaps to affift the Action of each other.

The ultimate or smallest Vessels which convey the most thin nutritious Humour, are here intended. We are not capable of discerning the fmallest Arteries by the Eye, unless perhaps some of them which are as large as small Threads: but the smallest Arteries in the cortical Substance of the Brain, terminate at length into invisible Arteries, which themselves open into the smaller Tubuli of the Medulla. But if this Mechanism takes place in the Brain, why may it not also obtain in other Parts? especially where the Arteries become as small as those in the Brain and Cerebellum, being little or nothing larger than the Tubuli of the Nerves themselves.

§. 398. At least it is evident, that every Branch of an Artery in a Muscle is furnished with corresponding Veins 1, which uniting form a larger Vein, whence the sanguiserous and lymphatic 2 Vessels of a Muscle are derived.

If the Veins are exactly filled with ceraceous Injection, they will in a manner feem to compose the whole Substance of the Muscle. In the Heart there are innumerable Veins which open into the Vena Cava, into the right Auricle and the same Ventricle;

Ventricle; but the Division or Distribution of all the Veins is always answerable to the Ramissications of the Arteries. Fi

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\* There are many Anatomists unwilling to allow that the Muscles have any lymphatic Vessels. But if there are Arteries, there must necessarily be returning Veins: but that there are Arteries of the smaller Series in Muscles, is evident from a Repletion of them by Injections, which enter smaller Vessels than those naturally destin'd for red Blood; and therefore it will follow, that they must be accompanied with Veins for returning the fubtle Humours of those small Arteries again into the Blood. The Nerves themselves do not terminate in blind Extremities which are not pervious; but they exhale continually some Part of their Contents, and others discharge their Contents into corresponding Veins (§. 292.): which Veins discharge their Contents into the smaller and larger Lymphatics. Even there is no great Difficulty in demonstrating the lymphatic Vessels of a Muscle by Experiment: for if the subclavian Vein be tied in a living Dog, and then a fecond Ligature made further on towards the Arm, the Course of all the Lymph flowing from the Head, Thorax and Abdomen to this Part will then be stopped: and if you dissect the Dog after Death, you will perceive innumerable lymphatic Vessels, not otherwise conspicuous, arising from all Parts of the Body. Nucke has also demonstrated Lymphatics in the Heart, and figured them in various Parts of Animals which he has prepared, which I have frequently contemplated with much Pleasure while that Anatomist was living.

§. 399. But the Tendon-of a Muscle being strictly examined, divides itself into as many Fibres

Fibres 1 as there are in the Muscle itself: but with this Difference, that the Cavity of a muscular Fibre, diminishing from its obtuse Belly, conjoins together into one accumulated Body, which is stronger 2, harder, drier, narrower, and almost destitute of visible Vessels. notwithstanding the small Vessels here appear innumerable and distinct by the Ruyschian Art of injecting 3, and distributed throughout every Point of the Tendon; and from a strict Combination of these accumulated Ends of the Fibres, the whole Tendon of the Muscle is formed, and may be very properly termed Aponeurosis 4, or an Addition to the Nerve. though the Name was given upon another Occasion. Of two such Muscles (§. 392, to 399.) connected in opposite Directions, almost all the larger visible Muscles are formed.

The deltoid Muscle may be readily divided into twelve smaller Muscles (per §. 392.); but to these twelve smaller Muscles, there are also twelve corresponding Tendons united. But the Division may be again continued in the fame Muscle almost to any Degree, infomuch that it will remain divifible as long as the Senfes can trace it. And as the fleshy Belly of each Muscle, and its several Fibres, are covered each with their distinct Membrane; fo likewise are the white Vesiculi and Fibres of the Tendons themselves: the Number of Vesiculi and Fibres in the Tendon corresponding to the fleshy Fibres of the Muscle; so that there is not any fleshy Fibre, but what has its corresponding Fibre in the Tendon. One may even truly fay, that the Muscle is the Tendon dilated, and

and that the Tendon is the Flesh of the Muscle contracted; since the Fibres which were very distant from each other in the sleshy Belly of the Muscle, run together into closer Contact and Cohesion in the Tendon. In the sleshy Part of the Muscle the Nerve is a dilated Membrane, but in the Tendon it is a contracted Membrane destitute of any Cavity, and is so much harder or more compact in the Tendon than it was in the Flesh, as the Tendon of the Muscle is smaller than the Muscle itself.

The Tendo Achillis sustains a thousand Weight without breaking: and it is a common thing for the Butchers to suspend the whole Ox upon Hooks

paffed through these Tendons.

A small Segment of an injected Tendon appears perforated with many Vessels, which are divided by the Knise. Ruysch macerated a Muscle for some time in pure Water, and then injected its Vessels after his manner, which he kept secret; and then upon cutting off the Tendon from the Bone, it appeared elegantly painted with a red Colour, insomuch that I have manifestly observed both the red Arteries and cellular Membrane placed about the Fibres of a Tendon, which was prepared by Ruysch.

The whole Muscle is composed of Fasciculi, which are resolvable into smaller Portions or Bundles; and the same Division may be continued surther by the Microscope, when the Eye itself can no longer suffice. It may be therefore reasonable to suppose, that what obtained in the large Part of the Muscle may also take place in like manner in those of the Tendon; and as the Muscle consists of nervous Threads, which do not touch each other, but are distinguished or separated by the Intervention of Arteries, Veins, and a cellular Membrane:

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therefore the like Fibres or nervous Threads are continued only at a less Distance from each other in the Tendon; whence the Ancients properly enough called the Tendon Aponeurosis, which is as much as to say, a Production or Continuation of the Nerve.

§. 400. The red 1 Colour of every Muscle therefore proceeds from its contained Blood, which being washed out, the Muscle looks pale. But the Bulk of a Muscle depends on the Repletion of its Arteries, Veins, and oily Cells; as also more especially the Repletion of its lymphatic Vessels. Hence therefore arises the Leanness 2 or Atrophy which accompanies old Age. And from hence also it is that the Muscle shrinks so much by an accurate washing 3 of it, or by long boiling. And yet we fee, that in old Age an Atrophy 4, and in thin Habits, that the Muscles retain their Motion; and that this Motion may be performed in Muscles which are not red, is evident in Insects 5 which have no visible red Flesh.

Arteries, in order to make a Preparation of the Heart, it returns through the Veins at first bloody, aftewards more dilute, and at length quite lympid, till the Heart itself appears white, but entire, and without any Alteration of its Structure. But even without this anatomical Preparation, those Muscles which are almost perpetually exercised with Motion, look naturally pale and colourless, such as the Stomach, Intestines, Urethra, Bladder, &c.

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<sup>2</sup> Oxen which are brought from the North in the Month of February, do in the space of another Month become Fat: I visited a Patient afflicted with the Colica Pictonum, which is a wonderful Difease usually terminating in a Palfy; but the Muscles in this Patient were so much wasted, that there was a Cavity betwixt the Radius and Ulna fufficient for one's Finger to be contained; and in short, he seemed in all respects a Skeleton cover'd with Skin. But yet there is some Hopes that he may recover, and there are more than a few that I have cured in this Condition; which is a manifest Sign, that in such a State there is every thing remaining which is necessary to the Muscle. In old Age the Cheeks and Calfs of the Legs fall away, the Skin becomes wrinkled, and the Muscles in a manner disappear.

Water, then boiling it, and again macerating for a confiderable time with warm Water, dissolved that Muscle into Fibres so minute, that they seemed to resemble Smoke or Vapour: but by this Preparation the Bulk of the Heart is surprisingly diminished, nor does it preserve its natural Fabric. The Bulk therefore of the Muscles denotes the Degree of their Distention or Repletion of their Arteries, Veins, lymphatic Vessels, and oily Cells. But that Part of the Muscle upon which its Motion depends is very different from the Artery, Vein, Nerve, or cellular Membrane; nor is there any Oil nor red Blood required to produce this Mo-

tion.

An Atrophy is a Disease that only consumes the Fat and Lymph, leaving the Structure and Action of the Muscles: thus it is with very lean Horses that are violently exercised. A phthisical Patient who was almost consumed, did neverthe-

less easily and readily move all the Muscles of his Body. I saw an ingenious Englishman, who was returning from France, so much consumed by an Atrophy, that only the hard Bones remained, and all the Fat was even wasted in the Orbits of his Eyes: yet he could talk very distinctly, and moved his Fingers very exactly; so that the Parts in the Muscle which perform its Motion, may remain when the Muscle itself is almost reduced to nothing; for the solid Fibres in a Muscle are not injured in a Consumption; and therefore all the Parts of the Head, the Encephalon and sensitive Organs continue perfect to the last.

The Flea which moves swifter than any other Insect, has nevertheless its Muscles which move the salient Legs of the Insect of a white Colour, and their Structure appears the same as in the Grampus Whale, which is as vast an Animal as

the Flea is minute.

§. 401. The Fibres (§. 393, 394.), the Facciculi of them (§. 396.), the Arteries (§. 397.), and the Nerves (§. 395.), are all distractile or capable of Elongation without breaking both in the living and the dead Animal, notwith-standing they are continually in the State of Tension, and endowed with a Power of contracting 2 themselves; for being cut asunder, they contract or shorten very much, diminish in Bulk, and draw themselves up into a fort of wrinkled Surface, while their contained Juices are at the same time expelled 3; hence therefore they appear to be continually kept in a State of Violence 4 or Distention, with respect to themselves, always resisting Elongation, and always endeavour-

endeavouring to contract or shorten themselves: but this much more in the living than in the dead Animal, and therefore one Muscle requires to have this antagonized 5 by another

Muscle acting in a contrary Direction.

2. If the Brain 6 be violently compressed, contused, totally obstructed, suppurated, or cut out in such a Manner as to let the Injury extend into the Medulla, then the Actions of all the voluntary Muscles cease instantly, together with all the Senses and Memory; but on the other hand, the spontaneous Motions of the involuntary Muscles still continue both in the Heart, Thorax, Vessels, Viscera, and vital Parts; but nothing of all this happens when the Brain which is opened remains free and found.

- 3. If the same Injury (No. 2.) be offered to the Cerebellum 7, the Action of the Heart immediately ceases, together with all the Senses. voluntary Motions, Respiration, and Life itself; but a vermicular Motion remains a long time after in the Stomach and Intestines, which may be again restored 7 in these Parts after it has ceased, and when these Injuries are removed in time.
- 4. If the Nerve 8 of a Muscle (§. 395.) be compressed, tied with a strict Ligature, corrupted or cut afunder, all the vital and voluntary Motions of that Muscle is then quite abolished; and if the Trunk of a Nerve is injured in the same manner, supplying its Branches to different Muscles, they will all of them

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them be in like manner deprived of their Motion; but the Injury being removed without destroying the Continuity of the Nerve, the Functions of all the Muscles return as at first.

7. The same Injury being offered to any Part of the *spinal Marrow* 10, then the Action of all those Muscles is destroyed, whose Nerves arise from the spinal Medulla below the Part affected, while the Actions of those remain intire, which have their Nerves from above.

6. If the like Injuries are offered to an Artery 11, distributed to one or more Muscles, all

the fame Consequences follow.

7. The Tendon 12 of a Muscle in Action 13 (§. 399.) receives scarce any Alteration that is sensible; but the sleshy Belly of the Muscle (§. 393.) is much shortened 14, grows hard, pale, turgid, and protuberant or swelled, while the Tendons approach towards each other; and thus is the Part to which the Tendons are connected, drawn towards the other Part which is less moveable 15; which Action is called the Contraction of a Muscle, being much more considerable and stronger than the other natural contracting Force of the Muscle mentioned at No. 1.; and therefore this is not the natural, but acquired Force of a Muscle.

8. The Tendon of a Muscle out of Action continues the same as before; but the Flesh of a Muscle becomes longer 16, softer, more red 16\*, shrunk or collapsed 16 \*\* and flattened; and this State is called the Restitution 17 of a Mus-

cle to its natural Condition, though it is mostly performed by the Force of the Antagonist 18 Muscle; for the Antagonist remains flaccid, or unactive; the contracting of the other Muscle will continue of its own accord from the innate Force (No. 1.) prevailing, without being

counterpoized.

9. If one Antagonist Muscle acts (No. 7.), while the other remains unactive, and in the Condition of No. 8. in that Case an Inflection of the Limb follows spontaneously; but if both of the Muscles act at the same time, it is then held immoveable; if neither of them act, the Limb remains slack and indifferent to Motion, in such a manner that the least Excess of Force in either of the Muscles, made either by Subtraction or Addition, will incline the Limb its own way.

made alternately, even in a Moment 19, or the least sensible Instant of Time, in the whole Flesh at once throughout the whole Muscle; and thus are they reciprocally absent and present, without leaving any remaining Signs be-

hind them.

tery of a Muscle at Rest, or in a dead Animal, either produces or renews its Contraction, even though the Experiment be tried a considerable time after Death.

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13. The Limbs being bent by an external Force 22, even against the Inclination or Will, causes the flexor Museles to put on the State of Contraction or shortening (No. 7.) in the same manner as if they acted by their own proper Motion, only with a less Force.

14. While the Will remains undetermined 23, all the voluntary 24 Muscles remain equally full in all their Vessels, and equally disposed for Motion by the Blood and Spirits, which are equally dispersed throughout every Part of

the Body at one and the same time.

Every Artery, Vein, and muscular Fibre in a living Animal, with all the Membranes, are attached to some Bones, by which they are stretched out or fustained in a State of Tension, so that upon a Division of them either in the living or dead Animal, they fly back or recede from their mutual Contacts, so as to form a Space immediately after the Knife has passed through by the Retraction of each Fibre towards its Origin. I have often obferved this Contraction to a fixth Part of the length of some Fibres. Hence we are are taught that all the Fibres are maintained in a more diffracted or tense State, while they continue fastened to the Bones, than when they are cut off the Body; and we also learn, that at which ever End a Fibre or Muscle is divided, it will contract towards that End which remains entire, whether we suppose the fame to be its Origin or Infertion. But that this contractile Force of a Muscle is not inconsiderable, may be demonstrated by Experiment: for if a Muscle be laid bare in the Thigh of a dead. Dog, and a Weight fastened to the same Muscle, upon dividing the Tendon, the Weight will be

raised by the spontaneous contractile Force of the Muscle, by which it endeavours to become shorter than its natural Length; and this Phænomenon is observable in all the Fibres contained in every Part of the Body. But an animal Fibre may be extended much beyond its natural Length, and afterwards it will contract and recover its former Shortness, as is evident in Fiddle-strings, which are usually made of the Intestines of the smaller and more active Animals, fuch as Cats, Dogs, &c. being first well cleansed from all their Fat or Oil. Such a String or Cat-gut well twifted and prepared will fustain an immense Weight before it breaks: but if at length it breaks, the divided Parts immediately fly towards each End, and the whole String becomes much shorter than it was be-But it is not necessary to break the String, in order to observe its Contraction; for upon removing the extending Weight, or diminishing it to any Degree, the String will shorten proportionably. For Instance: If you suspend an hundred Weight to a very strong Cord of this nature, and then take off the Weight of one Pound, the Cord will shorten one hundredth Part of the Length which it acquired by the Weight; and upon removing another Pound, it will shorten as much more, and so on in proportion to the Diminution of the Weight; but yet so as to remain tense, as long as there is the least appended Weight, becoming shortest when all the Weight is removed. This contractile Force is possessed by all Cords or Threads, and arises neither from the Air, Heat, Gravity, or any external Power, but only from the simple and mutual Attraction of the Elements or Particles which compose the Thread, whose Force is overcome by the extending Power of the Weight; upon removing which, the distracted Elements

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Elements approach nearer to each other by the fame Force. Almost in the fame manner we fee that two Loadstones being drawn from each other by any Weight, while they remain within the Sphere of Activity, upon removing the Weights, they will mutually approach towards each other.

For the Elements or constituent Particles of each Fibre, do all approach nearer to Contact with each other; fince every distracted Body increases its Surface without increasing its Quantity of Matter; and when again the Distraction is taken off, the Parts by contracting recover a closer Contact, and diminish their Surface or Bulk, the

the Quantity of Matter remains the same.

<sup>3</sup> In the dead Body or Subject which lies under the Hand of the Anatomist, all the Fibres and Vessels contract themselves, and expel their contained Juices. The Arteries are so much diminished in their Diameters after Death (§. 213.), that there is no Comparison betwixt them and those of a living Animal; and they appear to contain a much thicker and darker-coloured Blood, while they expel their Lymph and thinner Juices into the Veins, fo as to appear almost empty; whereas in the living Animal they are always full. For the Arteries contract in proportion to the Quantity of their contained Humours which is evacuated, and they constringe themselves about the Remainder of their Contents. The Stomach, Intestines, and thoracic Duct, all continue to propel forward their contained Liquors even after Death. In an Apoplexy arising merely from a Deficiency of the Vis Vitæ, or Removal of the Force of the Heart, while all the Viscera remain entire; as also in a Swoon Life will be reftored, if the Humours or any Liquors are forced through the thoracic Duct.

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4 We call any State or Condition of a Body violent, in which it suffers some Alteration or Change by the Action of another Body; and the natural State we suppose to be the Condition which the Body acquires of its own accord, when left to itself; and from hence we are able to demonstrate. that all the Muscles of the human Body are constantly in a State of Violence. For the Fibres, Vessels. Membranes, and other folid Parts are extended by their Attachment to the Bones, and therefore they continually endeavour to contract themfelves into a shorter Compass. The whole Length of the human Body is determined by the Bones, when they are fufficiently firm; but when they lose their Resistance, all the Parts shorten. French Surgeon Saviard remarks, in the Observations which he made in the Hospitals of Paris, an Instance of a Man whose Bones became by degrees fo flexible, that towards the latter End of the Diforder the Radius and Ulna were as flexible as a Piece of Whale-bone; the Diforder was attended with immense Pain, for the Periosteum must neceffarily be subjected to violent Distentions in the bending of the Bones, until that Membrane is broke through, in the fame manner as when the nocturnal Pains are formed in the venereal Disease by Nodes in the Bones. Upon opening the Body, the Bones appeared like foft Cheefe, as if they had been boiled in Papin's Digeftor; and inflead of Marrow, they contained a watery and bloody Juice. From this Instance it appears, that the Fibres of the Muscles continually endeavour to shorten and inflect the Bones, which would certainly follow, if they had not that Hardness which is fufficient to resist the Contractions of the Muscles. Even the Eye itself demonstrates a contractile Power, fince after Death it appears contracted into Wrinkles,

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Wrinkles, whereas before it was smooth and ex-But yet our Senses do not perceive this Endeavour of all the Parts to Contraction, because it is equally diffused throughout every Part, and the Equilibrium of it is not destroyed so as to break out into Motion. Suppose the Force of any Muscle by which it contracts itself to be equal to a hundred, and the diffending Force which opposes its Contraction to be equal to two hundred, it will not therefore follow, that the Muscle does not continue to act with the Force of a hundred, because we do not perceive that it overcomes the Refistance of two hundred by which it is opposed; but if you remove the Relistance of the two hundred, the Muscle will continually contract itself, not by any additional Force, but by the Power which it before exerted in Opposition to two hundred. For Instance again in the Weight of a Pound; if it falls upon a Table, it will not reach the Ground; but yet its Gravity continues to act, and it endeayours to reach the Ground with the fame Force which it received from the Motion; but if you remove the Table without giving the Weight any Impulse, it will instantly fall to the Ground, not by any new Force, but by the same Impulse of Gravity, by which it before endeavoured to de-Suppose again an exquisite Balance has a thousand Pounds in each Scale, they will be sustained in Equilibrio by the Equality of the contrary Forces, fo that neither of them will descend; not because the Weights do not exert the same Force to cause them to descend, but from the Equality of the contrary Powers destroying each other. again you cast but a fingle Grain of Sand into one of the Scales over and above the other Weight, it will descend and overcome the Power of its Antagonist, not from the Weight of the Grain of 0 4

Sand, but from the Inequality which it makes betwixt the two Powers.

5 Every Muscle is provided with its Antagonist, except where the Elasticity of the solid Parts is sufficient to equal their Resistance or contractile Force, of which we have an Instance in the Intercostals, but the Effect in both Cases is the same. If it was not for this Equality in disposing of the Muscles, the Figure of a Limb could never be changed from the Posture which it before obtained, and a Limb once bent or extended would continue fo as long as the Person lived. But the antagonist Muscles are so disposed in Equilibrio, that a Motion may be readily produced and governed in every Part of the Body by the Influence of the Mind, either by adding to or diminishing the Force of any one Muscle. But the Reason of this Mechanism does not appear evident to all. We think a Man is at rest, when at the same time all the Muscles in his Body are in a continual Tendency to Motion; and yet none of the Limbs are moved, because the inflecting Powers are opposed by those which extend, and there is no Force exerted in one Part but what is opposed in another. When the extending Forces act with the Momentum of a hundred; and there is also at the same time a Momentum equal to the fame Number exerted by the inflecting Powers, it will therefore follow, that the Limb will be retained immoveable by the Equality of the opposite Forces, which, though considerable, destroy each other by their Equality and Contrariety. From hence we may be able to understand the Proposition which may at first feem a Paradox, namely, to increase the Motion of a Body by diminishing the moving Powers. In the extended Finger all the Parts feem to be at rest, when at the fame time a powerful Motion remains e-

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in the Muscles which govern that Finger: and this occult Motion in the Muscles will become manifest upon dividing the feveral Muscles, and leaving only one Flexor intire, for in that Case the Finger will be continually inflected without making any Addition to the inflecting Power. If the Force of fome Muscles is destroyed by a Palfy instead of the Knife of the Anatomist, the flexor Muscle will in the fame manner act as before. Suppose a Man sleeping with his Arm bent in an Angle; in that Man four strong Muscles act equally upon the Cubitus, namely, the Ulnaris Internus, the Radialis Internus, the Ulnaris Externus, and the Bicornis; fo that there is a confiderable Force exerted here towards Motion without producing any Effect. Suppose again one of the extensor Muscles to be rendered paralytic, fo as to destroy a fourth Part of the Force which acted upon the Cubitus, it will in that Case be certainly moved or inflected. For fince the inflecting Powers remain the same, and act with the Force of two, while the extending Force is equal to no more than one, the Flexors will therefore overcome the fingle Extensor and move the Limb, in proportion to the Deficiency in the extending Force. If an external Muscle becomes paralytic while the internal one is not affected, in that Case half of the moving Force being taken off, an Inflection of the whole Limb will follow, fo as to produce a very visible Motion, when at the same time a Diminution is really made in the moving Powers.

6 A Bull which is one of the fiercest and strongest of Animals, being first secured with Ropes, and then knocked on the Head with an obtuse Instrument, there follows a Rupture in some of the small Arteries of the Brain, by which the Blood is extravasated, compresses the Encephalon, and the Animal tumbles down in a Moment with a Palfy of all his Limbs, expiring foon after. If the Head of the Animal be opened after Death, you will find the ruptured Arteries which extravalated their Blood by the Impetus of the Blow; and therefore it was this Blood which compressed the Brain and produced the Stupidity and Death of the Animal. In one of the more frequent Causes of Death, like the former, namely, in an Apoplexy, the Blood-veffels are ruptured, the Blood extravalated, and the Brain itself compressed, whereupon all the Senses and voluntary Motions are abolished, the Body tumbles down paralytic, the Person seems in all Respects as in a deep Sleep, and in a little time after that Sleep Death itself follows. There was a Man at Paris, who may be perhaps yet living (An. 1727.) who went about begging with Part of his Brain exposed, having lost a considerable Piece of his Skull; and by giving this Person a Bit of Money, he would condescend to let the same Experiments be tried upon him which a Pressure usually produces in the several Diforders of the Brain. By a flight Pressure the Eyes were observed to look red, and he then imagined he faw Sparks and Flashes of Light, at length Stupidity followed, and lastly a deep Sleep with a Stertor as in an Apoplexy: and by the same degrees did this Person return to his Senses and the Use of his Limbs, so soon as the Pressure was removed from the Dura Mater.

Duverney made several judicious Experiments; he opened the Cranium of a living Dog, compressed the Brain, and observed that a sudden Apoplexy followed, attended with the Loss of all the Motions in the voluntary Muscles: and then making an Incision through the Dura Mater, he compressed the Cerebellum, whereupon the Death of the Animal suddenly followed, except only that the Heart continued to palpitate for a little time;

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and this we know it will do even after it has been taken out of the Body. Hence therefore we manifeftly perceive two Springs of Motion in the Muscles: fince the voluntary Muscles, which are directed by the Influence of the Mind, become paralytic by compressing the Brain, from whence therefore their Nerves must be derived; but the involuntary Muscles, as the Heart, Stomach, Intestines, and those of Respiration, continue their Action while the Brain is compressed, but are all immediately rendered paralytic, when the Cerebellum itself is injured; and therefore these last must derive their moving Powers from the Cerebellum. I had an Opportunity of feeing both these Cases in continual Apoplexies: one in a Person who came to the Hague, and immediately upon fetting his Foot out of the Boat, he fell down instantly dead: the other in a Grinder, who fell down apoplectic in the same manner, but his Pulse and Respiration continued, with a Snoring and Redness of the Face; and by Phlebotomy, with a thin Diet, he perfectly recovered in a few Days time. Thus, in the first Case, the extravasated Blood immediately compressed the Cerebellum, whereas here it only compressed the Cerebrum.

It has been said before, that the Motion of the Stomach and Intestines continues even after Death; and that even the Motion of the Heart itself may be recovered from its State of Rest, by inflating or forcing any Liquor through the thoracic Duct, whereupon the Heart will immediately renew its Pulsation, and in a manner begin a second Life: but then it must be observed, that this second Pulsation holds but for a little time, and after a sew Moments ceases, so as to be irre-

coverable again by any Means.

9 We faid before, that the Brain is the Principle from whence the voluntary Motions are derived: but the Force which is derived from the Brain to the Muscles can be communicated no other way than by the Nerves. Therefore if a Nerve is render'd paralytic, all the Muscles which receive Branches and moving Force from that Nerve. will be necessarily relaxed, or render'd paralytic likewife. If those five Nerves arising from the Neck, from whence all the Nerves of the upper Limbs are derived, be either compressed, eroded, or cut afunder, all the Sense of Motion in the upper Limbs will then perish. If the crural Nerve be laid bare in the Groin of a living Dog, according to the Experiment of Galen, and then tied with a Ligature, all the Muscles of the Leg and Thigh to which it is distributed become paralytic; and after turning the Animal loofe, when the Wound is fewed up, he draws that Leg after him, as if it was no Part of his Body, but as if it hung by a String, being quite paralytic and immoveable. There is another elegant Experiment of Bellini, not indeed extant in his Books, but published in the Italian Journal, and in the Acta Eruditorum Lipsiensia. He took up the Nerve of the Diaphragm in a living Animal, and upon compressing it, that Muscle which received Branches from this Nerve was render'd paralytic, namely, the Voice and Respiration were abolished: but upon removing the Compressure from the Nerve, and moistening it with a Spunge dipped in warm Water, the Sense and Motion of the paralytic Muscle gradually returned together with the Respiration. If a Person in Health sleeps upon his Elbow, and compresses the large Nerve which runs along just within the Edge of the Elbow, the Sense and Motion of the Fore-arm will be abolished,

ed, and the Man upon waking will be surprised to find his Arm insensible and immoveable; but upon rising up and setting the Arm at Liberty, the Parts recover their Sense and Motion gradually, with an uneasy tremulous Sensation being selt at the same time. From these Experiments I think it is sufficiently evident, that the Principle or immediate Cause of Motion in the Muscles does not reside in the Fabric of the solid Parts, but in the

Force of the Humours derived into them.

10 An Obstruction of the Brain by Compressure. or otherwise, destroys the voluntary Motions; because the Nerves, which are the Authors of those Motions, are derived from the Brain. But the fpinal Marrow fends Branches only to the lower Parts of the Body; and therefore an Impediment or Injury in the spinal Marrow will only injure those Parts which receive Nerves from the spinal Medulla beneath the Impediment. I faw a Goldfmith who had a Fracture in the Vertebræ of the Loins at the Os facrum: and here there was a Palfy of all the Parts below the Injury; the Semen, Urine, and Fæces of the Intestines came away involuntarily, and without the Knowledge of the Patient. But whatever Parts are feated above the Injury in the spinal Medulla continue in their found and natural State, because their Nerves are derived from that Part of the spinal Medulla to which no Injury has extended. There was a certain Vintner of Leyden, who was by Nation a Walloon, a very jocose Man, who by falling from the Ladder of a Mill, while it was turning round by the Wind, fractured the Vertebræ of his Neck; whereupon the Physician being called, advised them to carry him home, for he had not above an Hour to live: but yet even in the midst of so much Danger, the ridiculous Fellow could not for-

bear jefting, and faid, That he had nothing more to complain of than that all his Limbs had deferted him, like as unfaithful Soldiers desert their Sovereign. He could breathe, think, and will freely; but then his Arms and Legs remained stiff and immoveable, without regarding the Influence of his Will: for the Nerves of the eighth Pair, with the Intercostal and ninth Pair remained free, so that the Heart, Lungs, Stomach, Viscera, and Organs of Speech had their proper and free Motions. But he had no long time to jeft; for foon after he grew stupid, and at length apoplectic, expiring in a deep Sleep, namely, because the extravafated Blood which compressed the spinal Medulla ascended into the fourth Ventricle, where by compressing the Cerebellum it put a Period to Life.

If the axillary or any other Artery be tied in a living Dog without injuring the Nerve, both the Sense and Motion of the Muscles perish in the same manner as if the Ligature had been made upon the Nerve itself. This Experiment was first made by Swammerdam, and was afterwards repeated and confirmed by many Experiments in Tuscany by Steno.

Whether it be a Muscle which governs some Limb, as in the Biceps of the Arm; or whether it terminates or circumscribes a Cavity, which is closed with an Orifice to which Action the Sphincters belong; or whether they belong to that Class serving to propel the Humours through the Ves-

fels, of which the Principal is the Heart.

The Tendon, in Fact, becomes a small matter longer by the Force of its Contraction, which tends towards the Center of the Muscle: but this Elongation of the Tendon is too inconsiderable to deserve the least Notice.

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14 The voluntary Muscles as well as the involuntary are equally contracted or shortened as well as diftended throughout every Point of their fleshy Substance, while they continue in Action. Any Person has it in his Power to try this Experiment upon himself, for if he bites any thing hard, or shuts his Jaws close, and at the same time applies one Hand to his Cheek while the Fingers of the other Hand are introduced into the Mouth to feel the Masseter on the other Side, he will perceive it become harder and more diffended in the Action. while he endeavours to elevate the lower law and press it strongly against the upper. In general, all the Muscles of the Body become hard and turgid only by the Influence of the Mind. I have feen fome Posture-Masters who in public Shews have resembled dead Bodies, in order to which they contracted all their Muscles in such a manner, as to render every Part stiff and immoveable, so as to be easily carried and treated as a Carcass by their Companions. That kind of Spasm or Contraction of a Muscle, which is called the Cramp, renders the Muscle so hard that it feels like Iron. If you open the Thorax of a living Dog, and make an Incifion in the Pericardium, you will perceive in what Manner the Heart contracts within its Capfule, and it will appear pale, bloodless, and turgid or swelled. If you observe the Motion of a Muscle in an Animal after the Skin has been taken off, you will fee that at every time of the muscular Contraction, it will become turgid and fwelled; and therefore the fame Cause which produces the Motion of the Muscle, does also at the same time render it tumid and hard. But if this Hardness and Distention of the Muscle be too great, the Muscle is thereby so much injured as to become paralytic, and frequently to produce Convulsions. There

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15 There is not any Part in the whole Body but what is capable of some Motion: Geometricians observe that all the Actions are in an inversed Ratio to the Refistances; and therefore the Effect produced by the Motion or Contraction of a Muscle is in proportion to the Reliftances of the Parts into which the two Ends of the Muscle are inserted. If the upper Ribs give the Resistance of a hundred to the Action of the ferratus anticus Muscle, and the Scapula gives the Resistance of one, while the Muscle contracts itself each way both from the right and left, the Scapula will then be drawn a hundred Parts of the Space towards the Ribs, while the Ribs are drawn one Part towards the Scapula. But when the Ratio of the Motion of one Part is fo very small with respect to the Motion of the other. that of the least is scarce observable, and is therefore usually esteemed the fixed Point. But if the fixed Point to which the one End of the Muscle is fastened has an infinite Refistance with respect to the other, it will then remain immoveable, and the other Point only will approach towards it. But if both Ends of the Muscle meet with the same Resistance, then they both pass through equal Distances or Spaces towards their middle.

16 The lower Jaw of a Person in Health, who is neither soolish, desirous of hearkening to something, nor paralytic, is always shut or drawn up: but in the strongest Person while sleeping, it is relaxed or let down by an Elongation of these Muscles by which it was before elevated. If you touch the masseter Muscle with your Finger, you will not only perceive it swell and grow hard during the time of biting, but you will also perceive it relax or elongate alternately; for it is absolutely necessary for a Muscle to swell when it is shortened, by adding that to its Breadth which is diminished from its Length.

white and hard at the time of Contraction, and at the time of Dilatation, the Heart appears red and flaccid. Therefore in the Contraction of a Muscle its Blood is discharged. But this Appearance cannot be well observed in all Muscles because the Fat obscures their Alteration.

pressing Laomedon against his Breast, the deltoide and pectoral Muscles are represented protuberant almost like Globes, while their antagonist Muscles appear soft and flaccid. And this is the principal Art of Statuary, namely, to make all those Muscles strong which are concerned in giving that Posture to the Body which the Figure or Gladiator represents, by fixing the Risings and Excavations in their proper Places. Whenever the antagonist Muscle is at rest, it is always relaxed; but when a Muscle is contracted it must necessarily gain as

much in Thickness as it loses in Length.

We faid before that every tense Fibre in the Body is capable of contracting itself into a smaller Length; but the Power or Force of any Muscle, as for Instance, any of the Flexors is estimated by the Access of the Powers, by which it overcomes the Refistances which oppose its Contraction: and therefore it manifestly follows, that if you relax a flexor Muscle which was before in Action, the natural Force of the Extensor which was before overcome will restore the Equilibrium and recover the natural Posture of the Part, in which Action the Muscle is opposed on all Sides from being shortened, while the Extensor recovers its Shortness, and the Flexor which was contracted recovers its former Length. Both the Flexor and Extensor are now in the least State of Violence, but yet they continue in fome degree of Extension or Violence, since neither

of the Antagonists permit the other to be so much shortened as it would if left to itself; but this Violence being the same in all the Muscles of the Body, is from the Equality or Justness of its Proportion render'd infensible to the Mind. The Arm of a Person hanging out of Bed, seems to have its Muscles at Rest; but yet they are not quiescent, but support each other in Equilibrio, and manifest their Action as foon as ever the Equilibrium is removed. In a Pair of Scales which have each a thousand Weight, there is no Motion follows, though the Tendency is extremely great. Wrestlers, who keep their Limbs stiff and suspended, feem to exert no Force, even when they labour with all their Strength to support themselves; but that they do labour, may be known from the Artifice by which the one overcomes his Antagonist. while the other endeavours to turn himself so as to fall uppermost. But it is not always necessary for one Muscle to be antagonized by the other, for that may be done by the Weight of the Part to be moved; as for Instance, the lower Jaw with respect to its Elevators, or the Elasticity of the Part, by which it recovers its natural State, unless altered by the Muscle, as in the Antagonization of the intercostal Muscles, or even the Weight of the ambient Parts themselves, &c.

18 The Back or Spina Dorsi is held direct, with no small Force, by the Assistance of many and strong Muscles, which are called the Extensors of the Back and Loins. These Extensors are antagonized on the Forepart of the Body by Flexors, which in most Parts of the Body are stronger than the Extensors, so as generally to cause the Articulations to be a little inflected, and moderate the Extension within certain Bounds. Suppose now all the stever Muscles to be suddenly relaxed,

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while the Force of the Extensors remains as before, an Opisthotonus, as it is called by the Ancients. will certainly follow, not because the Power of the extensor Muscles is increased, but because the Refistance is removed which was made by the Flexors. It is not therefore necessary, as many have falfly imagined, for the Force of the Muscles to be increased in order to produce Convulsions; for it is fufficient only to render the Forces of the Muscles unequal among themselves. Hence therefore if any Part of the Brain is injured, fo as to render the Muscles paralytic, which derive their Nerves from that Part; in that Case the antagonist Muscles will contract themselves by their prevailing Force: and from hence follow Convulsions, even in extreme Weakness; and at the time of Death, Convulfions generally precede, which are usually called Stretching out.

19 Reason teaches us, that there must be some Interval of Time betwixt these Actions; but the Space is nothing with regard to our Observation, as it is infensible; even in the very Instant of Time that I incline to extend my Arm, fo foon does it follow without the least sensible Interval; and at the fame time a Change is made in all the Extensors; and if I alter my Inclination to bend it, it instantly follows. But these are simple Motions; yet are there others extremely complex, performed without the least sensible Succession of We readily speak a Word in a Moment; whereas every Letter of that Word requires many different Motions of the Muscles belonging to the Glottis, Fauces, Tongue, Cheeks and Lips. So many different Motions pass through so many different Degrees thus readily, by the Influence of the Will, in an Instant of Time; so short, that it

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cannot be measured by any Instrument.

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This Experiment was formerly tried by Wepfer and Peyerus, who injected warm Water into the thoracic Duct, which excited a vital Motion in the Heart, but somewhat weaker than in Life. The Experiment has been since tried by Swammerdam, at Paris, and in Helvetia. Peyerus injected the Arteries with warm Water in a Dog killed three Hours before, whereupon the Muscles were suddenly contracted. Cowper observed the like Phænomenon in several Muscles: he injected, for Instance, warm Water into the crural Artery of a dead Dog, and immediately various Motions of these Muscles sollowed, which one would expect to receive their Blood from the same Artery.

21 This is one of the more difficult Experiments; but yet we see manifestly in the Heart that its Bulk is not much diminished, even when both its Cavities are emptied, and the Sides brought towards each other. When I move my Forefinger from the Wrist towards the Thumb, I then eafily perceive a Swelling of the Muscle betwixt the two Fingers; and by applying the Fingers externally to the Maffeter, with three Fingers internally within the Mouth, comprehending the Mufcle betwixt, moving the lower Jaw at the same time, or biting with a confiderable Force, the Muscle will be then perceived to swell both internally and externally, and will repel the Fingers with a confiderable Force, when at the same time the Muscle is limited in its Contraction by the meeting of the Teeth in the two Jaws; from whence we may conclude, that if the Masseter is not shortened at the time of biting, notwithstanding it is swelled, its Bulk must be then increased. Another Experiment has been tried by Borelli: he ordered a Rope-dancer to lay his Body flat upon the Rope so as to find an Equilibrium, and then to

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to endeavour to move one half of the Body, while the other was at Rest; but the Trial did not succeed, for whenever the Rope-dancer endeavoured to move the right Side of his Body, he could not prevent the left from falling, unless he exerted a Motion on that Side like the former. Borelli then ordered a Man to fit down in a Bath, and to keep his Body quiet, and after that on a sudden to move all his Limbs with a confiderable Force, and yet the Water maintained the same Height in both Cases; so that this last Experiment was equally useless, since there was as much derived from the other Parts of his Body, as occasioned the Turgescence or Swelling of the Muscles. Glisson has left us another Experiment, which feems to demonstrate, on the contrary, that the Muscles increase their Bulk at the time of Contraction. He placed a large and tall Glass full of Water, so fecurely that it could not move any way, and then inferting his naked Arm at Reft, and in a manner as if it was paralytic, he accurately observed to what Height the Water ascended; after which endeavouring to contract all the Muscles, he strictly observed whether the Water which filled the Vessel made any Ascent or Descent; and he found that at the first Instant it descended a little, afterwards stood at the fame Height, and upon a violent Contraction of the Muscles rather ascended; namely, that in the first Instant of time the Muscle diminished by expelling the Blood, but afterwards increased in Bulk by the Reception of Matter from the Nerves, If we only suppose the Water to have descended, and at the same time consider the great Force with which the arterial and venal Fluids are preffed out of the Muscle in its Contraction, when at the same time the Muscle itself either increases in Bulk, of at least receives no fensible Diminution, we may conclude

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fion of some Fluid, which enters and tumifies the Muscle with a moving Force. And that this is a true Deduction, is demonstrated by the Experiment of all the Muscles swelling at the Endeavour to move, even though the Motion itself does not follow, nor the Muscles become shorter. At least this Experiment of Glisson demonstrates, that the Motion of the Muscles is not performed by any Effervescence, since from thence would necessarily follow a Tumor sufficient to raise the Water. It even gives me some Uneasiness to find Borelli and Bellini assigning this Cause to muscular Motion, who were such good Judges in other respects.

22 This is another and very remarkable Experiment of Gliffon, who observed that the deltoide Muscle in raising the Arm became visibly shorter and more tumified, while its Tendon elongated, and therefore that very Muscle seemed to increase its Bulk at the time of Contraction. At another time he ordered the same Man to depress the Arm with all his Might, while at the fame time two strong Men endeayoured to lift his Arm up, so as to overcome the Resistance of the single Man; the Event was, that the deltoide Muscle became shorter even though it was at Rest, and swelled confiderably, while the Arm was elevated contrary to the Refistance of the fingle Man. This Experiment may be made in some of the interossei Muscles without the Affistance of another. any Finger to be drawn outward, and at the fame time with the other Hand thrust the Finger more forcibly inward, and you will then perceive the interoffeous Muscle swell in the same manner as is usual in muscular Motion. The Reason of these Phænomena is as follows: A Muscle while relaxed and elongated receives fo much more Blood, as its Reliftance

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Refistance is less than before; and therefore the deltoide Muscle in the first Experiment received more Juices, fince it spontaneously swelled by the Approximation of its Fibres; but when relaxed. the Blood and Humours will find a more ready Passage, and flow in a greater Quantity, as being excluded by the Straining or Contraction of the antagonist Muscles; and therefore this Turgescence of the Muscle is rather fanguine than nervous, nor does that Hardness follow in it, which is observed in the voluntary Motion of a Muscle.

23 This is a Proposition so evident, that it admits of no manner of doubt; for if the Condition of a Muscle is not altered by the Mind or Will, in that Case the Spirits or Juice of the Nerves will flow equally and constantly from the Brain into all the Muscles alike; nor can any Change be made in the Muscles by the Heart, which equally propels its Blood by the Arteries through every Part, as we experience when all the involuntary Motions continue, while the rest are abolished in Sleep. In Sleep therefore none of the voluntary Muscles will prevail, or be brought into Action, but only the vital Organs will labour, as the Heart, Intestines,

Stomach, and respirative Organs.

There is no room to doubt, but that there are feveral voluntary Muscles in the Body which operate only from Custom by the Influence of the Mind, of which by continued Use we are insensible; which Muscles taking their first Action from the Command of the Will, do nevertheless afterwards continue to operate in a manner as if it was spontaneously. We often walk at the same time that we are thinking or talking upon divers Affairs; and when we first wake out of our Sleep in a Morning, we fit up in the Bed, and throw our Muscles into that Posture to which they have been accustoaccustomed through the whole Course of Life, without giving them any sensible Command by the Will.

§. 402. From duly confidering the several Phænomena 1 before-mentioned (§. 401.), the Properties of the latent Cause 2 of Motion in the Muscles will plainly appear: such as,

1. That it is a Power capable of being pre-

fent and abjent 3 in the Muscle.

2. And consequently that it can enter into 4

and go out of the Muscle.

3. That it is derived into the Muscle from some other Part without, and again returns 5 to some other Part without the Muscle.

4. That it enters and returns in this manner in a Moment, and by the Influence 6 of the Will.

5. And that in the very Instant of time when a Muscle contracts, all the Fibres thereof are pressed or urged from within outwards 7
towards every Point of the Surface of the Muscle, even in opposite Directions.

6. That therefore it must be equally distributed at one and the same time throughout all

the Flesh of the Muscle.

7. And that it so dilates 8, fills and alters the Membranes of the Fibres, as to reduce them from an oblong 9 to a rounder Figure, increasing their smaller Diameter, and diminishing their larger, so as to bring the Tendons nearer to each other.

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8. And that this Cause must of Necessity proceed from the Brain 10, Cerebellum, and Origin of the Nerves; and that it is able to overcome the Resistances by which it is strongly opposed in the Muscles.

9. And lastly, that we must therefore conclude this Cause can be no other than a very thin fluid 11 Body 12, very eafily or quickly 13 moved, and that it must be forcibly 14 thrust

into or applied to the Muscle.

If a Man was to be born at once Adult with his Senses perfect, he would be surprised at the Perception of the Motions and Noises of the several Limbs and Parts of his Body, while they are in Action: but these we do not perceive, much less are we surprised at them, merely from Custom or Use, notwithstanding we hear and feel them perpetually; for it is a Property of the human Body to raise its Perceptions only from those things to which it is less accustomed.

There must of necessity be a Cause which renders a Muscle in Motion different from one at Rest; and as this Cause is unknown to us by not falling immediately under our Senses, it is to be therefore traced and discovered by the Appearances which it affords, taking care as we proceed to avoid mixing Falacy with Truth. But what we have hitherto faid, appears to be no more than what is supported by faithful Experiments; and therefore the Cause itself ought to be such as will correspond and agree with the Phænomena mentioned in the fourteen Numbers of the preceding Section ( ). 401.)

But fince there is no Muscle in the Body but what is capable of Rest and Action alternately, therefore the Cause of the Action must be capable of being present in, and absent from the Muscle; that is, it cannot proceed from any spontaneous Action in the Muscle itself; for if it was so, the Muscle would perpetually remain contracted.

Nor can this Cause reside in the Muscle itself; for if it dwelt there, it would perpetually act or produce its Effect uniformly alike, so that the same Muscle would be always either constantly relaxed or contracted: and besides this, it must not only enter from without into the Muscle, but it must also be equally distributed, and penetrate into every one of the smallest Fibres, so as to distend or fill them out.

When the Harp is struck by the lumbrical Muscles which move the Fingers, the moving Cause or Power must necessarily pass swiftly into and from each Muscle, so as to desert one and contract the other; and therefore this Cause must truly exist without, and be capable of passing from the Muscle by some Course after it has entered into it.

done with an incredible Swiftness, insomuch that it frequently exceeds, or rather escapes being measured by the least known Parts of Time. The Ears of musical Gentlemen are very learned, and divide Time first into the Battuta quadrata, or the largest Touch, which is the sisteenth Part of a Minute; and this Portion of Time they again distinguish into sour equal Parts, which sour they subdivide into sixteen Parts; so that at length sour Seconds of a Minute are divided into sixty-sour Parts, and the whole Minute of Time into 960 Parts. But skilful Musicians know how to run through the sixty-four Parts of the sisteenth Portion of a Minute so exactly, as to distinguish each Particle of Time.

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This Instance may therefore suffice as a Specimen of the sudden or swift Action and Relaxation of a Muscle; but if Musicians can thus minutely divide Time, the Action of the Muscles themselves must be much swifter than any mechanical Observation of the Musician possibly can, as we observed be-

fore in the Muscles of Speech.

7 The maffeter Muscle in the Act of biting fwells uniformly on all Sides, and repels the Fingers betwixt which it is comprehended; and therefore the Force by which the Muscle is indurated. must be diffused at one and the same time through every individual Fibre, directly in the fame manner, as when a Bladder dilates uniformly when it is inflated by a Pipe; fo that no one Part of the Muscle remains relaxed, while another is contracted; but all the Fibres at once become rurgid. which were before foft and lax. Befides this. in order for a Muscle to repel the Fingers from its Surface, it is necessary for the resisting Cause to operate with a Force continued from the Center of Gravity at one Instant towards every Point of the Surface of the Muscle, in the same manner as if a Thread fastened to a Center was to be moved all round from the Center to the Circumference at one Instant. When the Muscle is again relaxed, it grows foft, and yields to the Finger in the fame manner as if every Part was drawn from the Circumference to the Center by an infinite Number of fmall Threads.

A Muscle is composed of mere hollow Tubes or Threads; but all the Vessels in the Body grow hard when filled with Humours, and feel soft again when they are emptied. An empty Bladder may be thrown at a Person without doing any Injury; but if the same Bladder is filled with thirty Pounds of Water or Mercury, it may kill the strongest

Man: and therefore in order for the Muscle to become hard and turgid, it is necessary for all its Vessels, even the most minute, which are much less than those of Lewenboec and Ruysch, to become exquisitely turgid. But if this Repletion of the smallest Vessels is the Cause of the Hardness in a Muscle, and the Muscle is found to be indurated in every Part at the same time, it follows that the corporeal Cause of the Motion must be diffused on all Sides from the Center towards every Point of the Circumference.

9 Since the Fibres are filled by the Middle of their Centers, and their Centers are by that Means dilated, their Extremities must necessarily approach nearer each other, and each extended Fibre or Vafcule must become shorter. Bernoulli has demonstrated, that a circular Fibre which is perfectly flexible being given, and a Liquor is impelled into the Cavity of that Fibre, it will acquire no other Figure than that of a Sphere; for fince every Point is equally pressed by the Force of the distending Liquor, it can assume no other Figure than that of a Sphere; and if the Quantity of Liquor is fufficient, it will continue to be filled till it actually becomes a Sphere; but there its Repletion must stop, because a Globe is of all Figures that have equal Sides, the most capacious. Since therefore the Length of a Muscle in Action is diminished, its less Diameter or Thickness must be increased of necessity, and the reverse.

Prain is evident; because while that and its Productions the Nerves remain entire, and in their natural State, the Muscles are all capable of their Motions, but are deprived of their Action so soon as the Efficacy of the Brain and Nerves is abolish-

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But that it must be a very subtle Fluid, is evident from the infinite Number and Minuteness of the Vessels; nor yet would the Muscle be swelled by such a Fluid, unless it was to be impelled by some moving Cause. But we know not of any Fluid in the human Body more subtle than that which is derived from the Brain through the Nerves; since that Fluid is generated from the thinnest Parts of the Blood, so prepared in the Brain, as that the most subtle Parts only of it can enter into its Medulla and Nerves.

12 It is a common Property of every Body to be hard, or afford a Resistance to an external Impulse; and this Property of Matter, which has been infused into it by the wise Creator, is known under the Denomination of Impenetrability or Resistance, which is inseparable from any Body. But a Muscle resists on all Sides when its moving Cause is applied, and therefore the Cause of its Motion

must be corporeal.

The Italian Singers, whose Voices are bought at a high Price, know how to yield distinct Tones or Notes with so much Celerity, as to run through sixty-sour Shakes within the Space of one Battuta quadrata, or sour Seconds of Time. But the Cause of so swift a Variation is only a Dilatation and Contraction of the Glottis, so as to be wider at one time than at another: and this Variation again arises from the Action of the Muscles proper to the Larynx, and these again derive their Cause from the Brain, which is placed at more than a small Distance from the Larynx. It is therefore evident that the Muscles move with a very great Celerity.

The Force of the Muscles appears to be exceeding great. When the deltoide Muscle raises the Arm at full Length free from any additional Weight,

Weight, it exerts a Force, estimated equal to five thousand Pounds, by collecting together all the Resistances. But there are some Men who can write Letters upon a Wall with their Hand, even though there are sifty Pounds in Weight appended; whence the Force of the Muscles will appear to be very great and surprising.— Hitherto we have only proposed what is strictly agreeable to Reason and Experiment, and which must be allowed for Truth without any manner of Controversy, as being naked Experiments and Phænomena themselves; but it now remains for us to proceed further by the Assistance of reasoning.

§. 403. Now the Qualifications required in the Cause (§. 402.) are all found in the nervous 1 Liquor, and in no other 2 Humour; and therefore that Liquor is to be acknowledged for the true Cause 3; nor is it difficult to understand its Manner of Action.

The Liquor or Juice of the Nerves, which passes out from the cortical Substance through the medullary Tubuli, is the most sluid (§. 275.), the most solid, and like the Albumen which has been most highly attenuated (§. 276, 277.), is not the least acrid (§. 278.), upon which the Action of every Nerve depends (§. 284, 286.); but the Action of the Muscles results either entirely from the Nerves, or at least more from them, than from any other Cause (§. 401. No 4.): and therefore the nervous Juice is every way adapted to be the Cause of Motion in a Muscle.

This Cause cannot reside either in the arterial or venal Fluids, since they are equally made and distributed every Moment through all Parts of the Body;

Body; nor can it relide in the Loculi or Cells, in

which there is not any moving Power.

In Physics, the Demonstration of the Cause of any Appearance, is the demonstrating the Coexistence or immediate Connection betwixt the Cause and its Effect, or Appearance; as if the Cause of the Being A, resides in that of B; then the Entity B being supposed, that of A will also necessarily subsist; and as B is either increased, diminished, or totally abolished, so consequently will that of A: and the reverse, that is, as the Effect A appears either increased, diminished, or removed, the Cause B must be so likewise. A Person who sees Gold melt in the Fire will doubtless readily attribute that Effect to the Fire, and laugh at any Person who should contradict; but in this strict Way of reasoning we shall certainly find, that the Cause of Motion in the Muscles is contained in the Nerves.

§. 404. But from whatever ! Cause we suppose the Spirits to flow more fwiftly 2 from their Origin into one Nerve than into another, a greater Quantity of them will flow into the Fibre open to that Nerve; and this Fibre will be therefore more dilated 3, at that time losing its Elasticity, will yield to the Action of the Cause, and produce the Effects mentioned (§. 402. No. 7.); which Effects will increase, as the Cause continues or is increased, and therefore it will be tumefied throughout in the shortest Instant of Time, remaining contracted as long as it is thereto determined by the Continuance of the same Cause; and while this happens in the Fibrils, which are infinitely **fmal** 

finall and numerous as to Sense, the whole Effects or Appearances of them will be summed up and exhibited by the Muscle itself acting in the same manner.

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If you enquire after the Cause which produces this greater Celerity of the nervous Juice at pleasure, I must openly confess my Ignorance of it. The only Writer that has left us any thing tolerable upon the Subject is Dr. Ridley in his Treatise of the

Brain, chap. 12.

A Rest or Inactivity of the human Body follows, when the nervous Juice is equally diffributed from its common Fountain throughout all the Muscles of the Body; for at that time the contra-Stile Power of the Muscles is sustained by each other. If now in fuch a State of the Body the Nerve of the deltoide Muscle propels its contained Juice with twice the Celerity with which it passes through the Nerves of the other Muscles. in that Case the deltoide Muscle will receive twice as much Spirits in a given time, as is received by any other Muscle of the same Size, by which not only the Trunk of the Nerve will be distended, but as its Branches and the Fibres open to them refift the least, they will be also filled. And this Redundancy of the Spirits will be continually augmenting. For in the same manner as from the Doctrine of Galileo, the Effect of Gravity contibeally increases, while the first remains and continues to act; fo in this Instance the nervous Juice will be multiplied by a continual Accession, so as to become immense in the shortest Space of Time, that is, in the Second of a Minute. You would perhaps fay that this is a Proposition rather affumed than demonstrated, namely, that the nervous Juice is more strongly impelled into one Muscle

than into the rest; but this is an Objection to which all Hypotheses se open in whatever manner muscular Motion is supposed to be performed, whether from an Instum, Mechanism, or any other Cause. Certain it is that the nervous Juice must necessarily move, and that its Motion must continue from its Origin to produce this Change in the Muscles.

The Expansion of any flexible Vessel is in proportion directly to the Quantity of the impelled Liquor, and inversly as the Resistance of its Sides. Now in the Vessels of the Muscles the Resistance of their Sides remains the fame, but the Quantity of affluent Juices is increased, and therefore the Vessels will be dilated. Bernoulli demonstrates, that every Cylinder filled in its Center will fwell in the Middle, while the two Ends are brought nearer to each other, by which the Length of the Cylinder is shortened, till at length if the Vessel does not break, and the filling Force does not terminate, the Vessel will become perfectly spherical. But in this Case he adds, that the Cylinder will never be more than one third Part of its Length shorter; and therefore no Muscle can become shorter than one third Part of its Length. So long as this swifter Motion of the Juices into the Muscle remains, so long will it be harder; and upon removing the increased Motion or Afflux, it will be reduced to an Equilibrium with the rest of the Muscles.

§. 405. It therefore follows, that this Celerity (§. 404) being increased in one Nerve, the rest will be so much the less urged; and therefore these being relaxed, the Access of the Force in the contracted Muscle will act so much the stronger.

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The Quantity of Spirits in a human Body is not increased by muscular Motion, nor does the. Will generate the Cause of their Motion, but only determinates or directs the same. But the Spirits are retained without Loss, when the Body is at Rest, and all the Muscles held in Equilibrio: but when an increased Quantity of Spirits is determined to any Muscle, in that Case so much the less is fent to the other Muscles, as there is more determined to the Muscle in Action. If there are a thousand small Muscles, and one of them is filled by the Will with a double Quantity of the nervous Juice, then every one of the other Muscles will be deprived of a thousandth Part of the Juice which they would otherwise have had; and if the one Muscle in Action is expanded to twice its usual Thickness, all the other Muscles will be contracted one thousandth Part.

§. 406. From these two Causes (§. 404, 405.) all the turgid Fibres of a Musele will contract the Intervals 1 or interposed Spaces which lie betwixt them, together with the Blood-veffels which are there distributed, and with a confiderable Force; from hence the Veins will be emptied, the Arteries compreffed 2, and the groffer or red Parts of the Blood repelled, while the more fubtle 3 Humours are by the Force of the Heart urged on into the fmallest Vessels and Fibres: and thus the Blood being expelled, while the whole Body of the Muscle is supplied by the Nerves and Arteries with the more fubtle Humours, we perceive that the Action follows, and every Condition required by the moving Cause is satisfied; for that 06.

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that Part of the Body will be moved or drawn to which the Tendon of the contracted Muscle is fastened, provided it makes ever so little less Resistance than the Force of the Muscle which acts upon it.

A Muscle is composed of small fleshy Fibres, which are in a manner fo many Nerves expanded into impervious Cylinders; and betwixt these Fibres are interposed the other Vessels of all Kinds, fanguiferous, ferous, and lymphatic. Now when the Arteries, Veins, and nervous Fibres are filled with some equable Force, the Magnitude of their Arteries will be limited, and fo will also the Thickness of the nervous Fibres. If the Fibres themselves are increased in Bulk without any Alteration in the Vessels, then of necessity there will be an Alteration in both; for suppose there are four Arteries and four Bundles of Nerves mixed together in one Fasciculus of muscular Fibres, the Compression of the Arteries will be limited or determined to a certain Degree: but now suppose the Nerve to be increased as large again, the Diameter of the Artery will necessarily be subduple, and therefore the Arteries and Veins interpoled betwixt the Nerves will be compressed. Nor does it feem true which is affumed by some Authors, namely, that the Veffels of a Muscle are totally emptied at the time of its Contraction. It may indeed be admitted with respect to the Veins, but the Arteries are continually filled and dilated by the Force of the Heart. Besides, as much nervous Juice as any Muscle acquires, so much is derived from the rest of the Muscles; and therefore the other Nerves of the Body will be less filled, and make a less Compressure upon the Arteries: there-

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fore in all the other Parts of the Body there will be a less Resistance to the Afflux of the arterial Humours; fo that the Blood will pass from the Arteries of the contracted Muscle, into those of the adjacent Muscles which are relaxed. But the Veins will also propel their Blood in the same manner into the other adjacent Veins, when a Muscle contracts; and thus the Quantity of the groffer Humours will perpetually diminish or depart from the contracted Muscle, so much the more in proportion as it remains longer in Action, and the harder, paler, stronger and shorter will it be; so likewife will it be paler and more bloodless, and so much the greater Accession will be made of the Blood into the other Vessels, as there is a larger Quantity of Spirits determined to the Muscle. But all that Space which was before occupied by the expelled Blood, will be now filled by the Accession of Spirits and more subtle Juices; whence it is that the Muscle not only retains its Bulk, but maintains its Turgescence and Hardness, notwithstanding it has been deprived of so great a Part of the groffer Humours.

I must own myself to have been formerly pleased with the System of Tauvry, namely, that the Nerve spending itself upon the Anastomoses or ultimate Extremities of the sanguiserous Arteries, acted as a Sphincter to contract them, and stop the free Passage of the Blood from them into the Veins, while at the same time the smallest Vessels continued pervious beyond the Extremity of the

Artery.

Namely, the most subtle Humours of the smallest Arteries, which are like Nerves (§. 346, 402.) assisting the Operation of the Nerves, which are changed into muscular Fibres. These Juices being more plentifully sent into any Muscle, make

up for the Loss of the groffer Humours, which are expelled from the Muscle. There now remain fome Difficulties to be removed, concerning the Motion of the Muscles performed in this manner: fuch as, 1. How it is possible for such small Tubes, agitated by fuch an exceeding small Quantity of Spirits, to generate fuch powerful Motions, infomuch that Borelli should make the Power of the deltoide Muscle only to be equal to five thousand Pounds Weight. 2. Why so great a Force applied to fuch tender Fibrils does not fooner break them than raise the Weight. But to both these Questions Answers may be given from Hydraulics (§. 411.): for I have often raised eleven hundred Weight only by the Force of my Breath blown through a small Tube, which is certainly one of the most simple of Machines.

§. 407. But this Cause (§. 404.) ceasing, all the Parts are at once restored to a perfect Equilibrium with each other, as well by the Elasticity of the Fibres, and the equable or counterpoising Force of the other Muscles, as by the Reaction of the circumjacent Parts, which have been stretched beyond their Tone by the Contraction of the Muscle itself. Every 1 Appearance and necessary Circumstance therefore of this Motion (§. 401, & Jeq.) is thus satisfied by understanding the Fabric and Cause attending in the Muscle itself, only by assuming or supposing a Power increasing the Celerity of the Juice at the Origin 2 of the Nerves, which last is not to be reasonably expected to be accounted for (§. 27. No 10.)

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stance of the Encephalon (§. 289, & feq.)

Whether from the Mind? Thus it feems to be without doubt: but that the Origin of the Celerity begins in the Brain itself is most certain; but then where, or in what Part of the Brain does it operate? This feems to be in the common Senfory, that is, in the Confines betwixt the ultimate and smallest Arteries, and the Beginning of the medullary Tubuli (see 574.) But what Action is it that the Mind exerts upon the Nerve? Certainly I know not, nor does any one Mortal besides. -Whether or no it constringes the Nerve, and by that means propels the nervous Juice more fwiftly? Certainly there feems to be no other Way, by which that Juice can be propelled, than by a Preffure at the Origin of the Nerves. But in whatever Way it acts, whether by propelling the Juice, or by dilating the Nerve, and deriving the Juice; the Difficulty in determining its immediate mechanical Action will always remain, that is, it will always remain to be accounted for, in what manner the Mind can act upon elaftic Bodies which repel each other, so as to force them into the Nerves, We shall not in this Difficulty have recourse to the Opinion of Willis, by supposing it to operate as if Oil is mixed with Spirit of Vitriol; or a fermentable Acid mixing with the alcaline Spirit of the Blood, according to the Theory of Borelli.

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§. 408. The incorporeal I Faculty of Galen inflating the Muscles will be here of no Service to us; no more will the Mixture of a nitrous? Spirit of the Nerve with the Oil of the Blood rarefied or kindled into an explosive Power. Much les shall we be affisted by the Mixture of an acid 3 Spirit of the Nerves with the alcaline Spirits of the Blood, nor yet by an Ebullition of Æther 4 with the arterial Humours. nor yet an Increase or Diminution of the Power of Attraction 5 betwixt the most minute Parts of the Solids and Fluids: for these are all repugnant to Sense, the Fabric of the Organs, the Matter, Mixture, and Proportion of the Humours, with the Continuance and Number of the Appearances observable in this Action. Nor have we the least Occasion to call in their Affistance.

Hipprocrates very wifely diftinguished three Parts in the human Body, namely, the (ne excusual) contained, the (ne scorne) containing, and that (no evoguer) which impels; by which last he understands the Will or Action of the Mind diffinct from Nature, which he places in the other two, namely, in the Veffels and their contained Humours. This Opinion is expressed by Paracelsus in other Words, when he fays that he finds Vessels, Humours and Imaginations in the human Body. Galen formerly proposed an incorporeal Cause inflating the Muscles, which he takes from the Impelus faciens of Hippocrates. Even at the present Time there are many eminent Phylicians, who admit of no other Cause than the ( reveguer) Impulse of the Will Will to move the Muscles. I readily admit, that the Mind is the first Mover or Cause of Motion in the Muscles; but then I place the Exercise of its Action only in the common Senfory: for in the Muscles themselves the moving Cause must be corporeal, which was not reliding there before the Contraction of the Muscle, as is evident from the Hardness and Resistance perceptible in a Muscle by the Touch, during the time of its Contraction. Even if the incorporeal Causes from whence the Origin of Motion in the Muscles is derived, were useful to be understood and explained, yet it would make no Alteration in this Course of Changes. which are made by corporeal Causes in the Muscle itself: and besides this, the Impulse of Hippocrates and Galen, which is immaterial, can never be conceived nor understood by us, fince we are altogether ignorant of the Manner in which God has connected the Body and Mind.

2 Willis observed, that well rectified Oil of Vitriol, or pure Spirit of Nitre, mixed ever fo gently with Alcohol Vini, produced a sudden Effervescence with so considerable a Force, as to break the Vessels if they were not very open. hence that Gentleman conjectured, that perhaps the animal Spirits might be of an acid Nature, but that the Blood abounded with oily Particles, and that from a Mixture of these two, an Explosion arose like that from a Mixture of Oil and Acid, by which the Motion of a Muscle might be produced. But here we may observe, that, 1. The Efficacy of the Mind is here equally required to determine the Mixture of an acid and oily Liquor more in one Muscle than in another, 2, It does not fufficiently appear, how the Mind could regulate or moderate such an explosive Force, so as to correspond to any particular Weight in a geome-

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and acid Nature of the Spirits, are the mere Produce of Imagination (§. 277, 167.) 4. Such an explosive Force of Oil and Spirits would destroy the Fabric of the Muscle itself.

3 It gives me some Concern to find Borelli and Bellini should admit these Hypotheses, namely, that an Effervescence should arise in a Moment betwixt an acid Spirit of the Nerves, and the alcaline Blood, in the same manner as if a Mixture of Spirit of Vitriol with an alcaline Salt in a Bladder. was to diftend the muscular Fibres, and contract the Muscle itself. But we have before sufficiently demonstrated, (1.) That the Humours of a healthy Body neither contain any Acid nor alcaline Salts. 2. And that supposing such Humours in the Body, there must be distinct Vessels, some for the Acid and fome for the Alcaline; when at the fame time there are no fuch Vessels in the Body, as are capable of refifting the corroding Power either of Acids or Alcalies. (3.) Admitting there may be fuch a Mixture in the Muscles, it will not explain, why fuch an Effervescence should cease in one Muscle more than in another, without keeping them continually in Action, fince the Afflux of the Humours into the Muscles from the Heart and Brain is continual, though more copious at one time than at another.

The Action of the Muscles was formerly derived by Cartesius and Bernoulli from a subtle Æther; to which add Sir Isaac Newton. Optics, Quer. 24.

This Hypothesis of Attraction is proposed by Keil, namely, that there are some Parts in the Blood endowed with a peculiar Force, by which they attract and repel each other; and which are sensibly at Rest, when they are mixed in a determinate

minate Proportion; but so soon as any one Sort of the Particles abound separately in a Muscle, they repel each other with a confiderable Force. in proportion to the Force with which they met or attracted each other; and this in the fame manner as Air. each individual Particle of which is not elastic nor real Air, but two or more of them together repel each other, and form Air. But fuppose we admit such an Hypothesis without any Demonstration, what would it avail against the Objections and Difficulties that may be raised against it. For though that Part of the Blood which makes the Attraction receives a quicker Motion from the Brain, this will not explain how those Parts only should remain in the Muscle which repel and extend its Fibres, while those Parts recede which made the Attraction; nor do we obferve any fuch Particles which thus attract and repel each other in the Fluids of the human Body. Certain we are, that the Particles of the thick Blood itself, do by their Viscidity strongly attract each other; but it would be an insuperable Difficulty to demonstrate that it contains elastic Air, or Particles which repel each other: nor can it be of any Force to apply those Properties to the Blood, which we observe in the Magnet, or in elastic Air, which are Bodies very different from the Blood itself. It would also be difficult by this Hypothesis to explain by what Means these Attractions and Repulsions could be fo fuddenly produced and quieted by the Mind, or how they could be fo conftantly and regularly continued by Internate Separations and Conjunctions, or Attractions, during the Space of a whole Day, as we observe in the Husbandman and those who lead a laborious Life. - I propose these Opinions to shew that the Phænomena of mulcular Motion cannot minate

be explained without the Affistance of a nervous Juice i and that the System which we have before proposed is every way sufficient, namely, that the muscular Fibres have such a Fabric, as resembles a small Pipe inserted into a Bladder, much after the manner of the Air-bladders in Fish, which by a contractile Force can discharge the contained Air, and by relaxing can admit more Air at the Pleasure of the Animal, according as it inclines to swim either towards the Surface or Bottom of the Water. Small Bladders of this Kind will swell suddenly if they are filled, and subside again as suddenly when the filling Power is removed.

§. 409. But this equable Influx of nervous Fluid happening at once in all the Mufcles of the whole Body, cannot at the fame time flow into the Heart while contracted, but is collected in the Nerves thereof; fo that this Mufcle being filled by the Auricles, Vena Cava. and pulmonary Vein, with Blood paffing into its Ventricles, and into its Substance by the coronary Arteries, where at the same time its muscular Fibres are filled by the Nerves; by these Causes the Heart is violently contracted in an Instant: but soon after the venal Blood, being in the mean time plentifully and forcibly brought into the Auricles and venous Sinus's by violently diftending their Sides, it compresses the cardiac Nerves which lie near them; while at the same time those cardiac Nerves which pass into the Heart by the Side of the Aorta and pulmonary Artery, are also compressed by the Expansion and Repletion of those

those Vessels; therefore the Heart becomes paralytic, and being relaxed is again filled; and by this means all the cardiac Nerves being set at liberty again, the Heart will be contracted, and in that manner will it continue to act and rest alternately. But with respect to the ultimate Action of the Muscles of Respiration we shall speak hereafter, at §. 601, & seq.

The Heart alone moves all the Humours in the Body, together with the folid Parts, and likewife all the Muscles; for if you do but take out the Heart, every Part foon loses its Motion and dies, except the Intestines, which continue their vermicular Motion a confiderable time after they have been taken out of the Body. It therefore now remains for us to examine how the Heart moves itself, fince it is that which moves all the other Parts in the Body. There are three Causes which concur towards the Contraction of the Heart, namely, r. The venal Blood which the Heart receives into its Ventricles out of the Sinus's and Auricles. 2. The arterial Blood, which being forced back by the Contraction of the Aorta, is impelled into the coronary Arteries. 3. The Efficacy or Power of the Nerves, which is communicated through the Branches of the eighth Pair and intercostal Nerve with the recurrent Nerve. Causes concurring produce the first Contraction of the Heart, whenever may be the time this first Contraction happens, or whatever may be the Cause which gives the first Impulse, from whence the Power of the first Contraction arises. So long as these three Causes operate in the Heart, so long will that Muscle remain contracted: but in the

very Instant of Time in which the Heart is contracted, the Causes of that Contraction are destroyed or removed. For, 1. The venal Blood, which being received into the Ventricles of the Heart stimulate it to Contraction, is all expressed into the Arteries. 2. And while the Heart looks pale in its Contraction, it also expels the Blood of the coronary Arteries, and the Juices contained in its own muscular Flesh, and in the Spaces betwixt the Fibres; and what was in the Arteries it repels into the Aorta, fince the whole arterial System of the Heart is without Valves; and the Blood which was in the Veins is at the fame time expressed into the Sinus, right Auricle and Ventricle, paffing itfelf foon after into the Arteries. 3. The third Cause of the Heart's Motion is somewhat more obfcure; namely, the Heart is separated from all the other Parts of the Body by a membranous Bag, called the Pericardium; nor is there any Communication betwixt the Heart and the other Parts of the Body, except by the four large Veffels, by which the Blood is conveyed from all Parts to the Heart, and from thence to all Parts again. So that from hence it appears, that the cardiac Nerves could take no other Course into the Heart, but through the Pericardium by the Sides of the large Blood-vessels. But there are few of the cardiac Nerves which accompany the Veins, and those which are the most powerful and numerous pass in by the Sides of the Arteries; but the pulmonary Artery and Aorta pass out of the Heart, joined close to each other; and close by the Sides of these two Vessels, the Nerves of the Heart collect themfelves in two Fasciculi or Bundles, one of which being the larger Plexus follows the Aorta, and the lesser accompanies the pulmonary Artery quite in a different manner from that in which all other Muscles

Muscles receive their Nerves; for in the other Muscles the Nerves never enter through the Tendons, but through the Middle of their most fleshy Part, as Vefalius has rightly demonstrated in Opposition to Galen, and as is truly represented in all the Tables of Eustachius. But fince this is the Course of the cardiac Nerves, and the Arteries being more violently expanded at their Beginning by the Blood thrown out of the Heart, than in any other Part of their whole Length, it follows, that the Nerves intercepted betwixt these Arteries will be compressed; for the Aorta and pulmonary Artery lie to close to each other, that they cannot be separated entire without much Labour to the Anacomit. But every Muscle, whose Nerve is compressed, becomes paralytic or relaxed (\$.401. No 4.); and also every Muscle, whose Artery is tied or compressed, becomes likewise paralytic: and therefore when the Heart contracts, it loses or deprives itself of the irritating Blood in its Cavities, as well as that of its Arteries, necessary to muscular Motion, together with its nervous Juice; whence it is evident, that a Relaxation or Dilatation of the Heart must necessarily follow immediately after its Contraction. But during the time of this Relaxation, the three Caufes of its Contraction will be again renewed, fo that a Systole will immediately follow its Diastole; which Doctrine was taught by no body before it was propofed by myself; and it may be seen demonstrated at large in mathematical Order, as I delivered it in my last academical Oration which is published. For, 1. The Aorta being very full of Blood received from the Heart to the Quantity of four, or at least (to avoid all Disputes) two Ounces, against which Blood the Artery and all its Branches act by their Elasticity; therefore the Aorta will contract by

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by its own Force fo foon as the Heart has emptied its Blood, and by that means Part of the Blood of the Aorta will be propelled into the coronary Arteries, which being at that time empty will give the least Resistance. 2. So soon as the Heart is relaxed, it ceases to exclude the venal Blood in the Sinus's and Auricles, in which the Blood was in the mean time collected; and upon the Heart's Relaxation, fuddenly forces itself into the Ventricles. in which there is a fort of Vacuum, which the Blood itself immediately fills. 3. When the large Arreries are contracted, they recede from the mutual Contact of each other, and by that means leave a free Space in which the Nerves lie uncompressed, whence more new Spirits will be easily fupplied to the muscular Fibres which were accumulated above the Compression in the Nerve, But upon the Return of the Power of the Nerves, the Heart itself is animated to a fresh Contraction; and as the three Causes of the Heart's Motion now return, there is no Obstacle to its Contraction: but being contracted, a Relaxation will confequently follow in the manner we before described. And thus is the proper Motion of the Heart itself continued alternately in a different manner from that of all other Muscles, purely by the Mechanism given to its Parts by the Creator.

This Question is much more difficult to solve even than the preceding; nor does the Power or Action of these Organs result from the Heart, since the Heart beats six, eight, or ten times with-

in the Compass of one Respiration.

§. 410. But how great this Force 1 is in a contracting Muscle, he only understands, who knows, 1. The Place into which the moving Tendon

Tendon is inferted into the Part to be drawn, with regard to its Distance 2, from the Center or fixed Point, about which the Motion or Flexure is made. 2. The Obliquity of the Direction through determined Angles 3, which are here for the most part very acute. 3. The Weight of the Part itself to be moved. 4. The Weight 4 of the Parts appended, and of that which is to be lifted, together with the Place to which the Weight is applied. 5. The Duplicity's of the Sum of those Forces required to produce or determine the Motion towards the fixed Point; all which has been mechanically demonstrated by Borelli.

There is no other Measure of Forces than by Resistances, in the same manner as there is no Magnitude but what is relative and determined by certain Measures. But those Quantities are called infinite, which are not reducible to any known Meafure. And this Power of the Muscles is determined not only from the Weight of the Limb elevated by the Muscles, but also by computing the Sums of all the Reliftances which are to be overcome or removed, in order to produce the Effect. two ftrong Men struggle together with equal Forces, there is a great Effort exerted by each, notwithstanding there is no manifest Motion follows: but if one of them prevails ever so little over the other, his Adversary is immediately thrown to the Ground, But hat Force by which the Conqueror overcomes his Adversary, is not barely the Excess of the Forces which produce the Effect, fince a confiderable, Power is exerted to equal the contrary Effort and Refistance of his Antagonist.

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When Mechanicians determine the Power of a Machine, they make use of the Comparison of Levers, namely, Lines which have neither Breadth, Thickness, nor Weight, being altogether inflexible, and supported upon some fixed Point, called the Hypomochlion, or Point upon which it moves. For altho' there are no Levers having thefe Conditions, yet the Effects are the same, since contrary Powers destroy each other, and as the whole Weight is entirely supported upon the fixed Point only, as De la Hire has demonstrated in his Mechanics. Such a Lever they divide for instance into four equal Parts placing the fixed Point or Hypomochlion in the middle, and by placing a Weight at one certain Distance from the Center, and a Weight three times less at three times the fame Distance, an Equilibrium is produced, and if the latter Power is a little more than thrice the first Distance, the Weight will be raised; but if the Weight is placed at three times the Distance, and the Power at less, then the triple Power will raise the simple Weight. But let us apply this Consideration to the Arm of the human Body, and compare the whole Limb to a Lever, placing the Hypomochlion or fixed Point in the Articulation of the Humerus with the Scapula, for it is in this Articulation that the fixed Point is feated, about which the whole Arm is circumvolved. We must next consider the Infertion of the Muscle, whose Force we enquire after, as for instance, the Deltoides which we find is inferted immediately after the Articulation itself; next a Weight is appended, for instance, to the Fingers: now in order to make an Equilibrium, fo much Force is required in the deltoide Muscle to raise the Weight in proportion as the Distance of the Weight is from the Center of Motion, Motion, and the Distance of the Insertion of the deltoide Muscle from the same Center of Motion. But then as the Arm is not a mathematical Lever, but is composed of Flesh and Bones which are themselves of no small Weight, the Force of the deltoide Muscle ought-therefore to be so much greater than the Weight of the Arm, as the Arm itself, than the Distance which is intercepted betwixt the Articulation and the Insertion of the Muscle, or Application of the Weight, and these are to be conjoined, and the first Ratio of the Powers is to be increased.

3 If now a Weight is applied to fuch a Lever, as we have before described, at one End, so as to draw the Lever from the Perpendicular, the other End of the Lever will be raised with a Force of the fame Momentum as that by which it was drawn downward, as for Instance, to an Angle of forty-five Degrees, then the depreffing Power will be fo much greater than the oblique Power as the right Angle of ninety Degrees, or as the Sine of a right Angle is greater than the Sine of an acute Angle of forty-five Degrees. But if you regard the Infertions of the Muscles, they will be found generally inferted at very acute Angles; as for Instance, if the deltoide Muscle arises directly above the Humerus, and is inferted into the middle of that Bone towards the Perpendicular, it will certainly make a great Diminution of the Power. Now as this Muscle is inserted obliquely into the Bone, it must necessarily exert so much greater Force, as the Sine of its Angle is greater which it intercepts betwixt itself and the Lever or Humerus; but if this Angle is diminished or reduced to nothing, and the Weight is applied according to the Direction of the Lever, there will then be a confiderable Loss of the Force, that is, if a Weight to

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is to be raised by the Arm in a Position parallel to the Horizon, it will require a Force almost infinite.

4 Which Weight is always the greater in proportion as the Power of the Muscle is applied nearer to the Center of Motion, and therefore the Power must increase in the same Proportion as the Weight exceeds. And therefore the human Arm is not to be estimated only at twenty Pounds Weight in calculating the Power of the Muscles. for it is immenfly heavier to the Muscles. are some Men who can write Letters upon a Wall with their Arm extended, while at the fame time they fustain a Weight of twenty or thirty Pounds appended to their Thumb and Fore-finger; whereas to extend the Arm in this Manner with fuch an appended Weight requires a Force equal to fifty thousand Pounds. In the Thigh, whose Center of of Motion is fixed in the Articulation of the Femur within the Acetabulum of the Os Innominatum, the Muscles are inserted so near the Center of Motion, that the Forces which they require in order to Motion may be eafily estimated at 100000 Pounds.

fome in England. He proceeded in the following manner: Let there be a Pound Weight suspended by a String sastened to a Hook, I say the String is then drawn with the Force of two Pounds: for the Hook endeavours to raise the String with the same Force as the Weight endeavours to depress it, and therefore a Force equal to two Pounds is applied to stretch the String. This is objected against by a certain Person as a Sophism. But he ought to have considered, that if the same String and Weight was to pass over a Pully, so as to form two Legs, if only one Pound Weight is sastened

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to but one of the Legs, the other will be drawn over the Pully with a Force equal to a Pound, unless a like Weight is appended to that End also: and therefore from this Confideration, if the Nail or Hook is taken for the Force of the Pully and one Weight fustaining a Pound, the Hook will appear to operate with a Force equal to the other Pound to prevent it from descending; for an Equilibrium would never be produced, unless one Pres. fure was to be deftroyed by another in an opposite Direction. It is therefore evident, that the Nail will fustain or stretch one End of the String as one Pound Weight, while the other Pound which is appended, firetches it with the like Force in a contrary Direction, and therefore the whole String will be extended with the Force of two Pounds by appending one. Thus it is evident, that the human Body exerts an immense Power to raise great Weights: and that to raise the Arm, which is ten Pounds Weight, requires a Force of twenty thoufand Pounds. Nor ought we from hence to accuse the Wisdom of the Creator, as wasting or bestowing fuch immense Forces without Necessity; for if the Powers were so applied, as to act in the least Compass with the greatest Force, the Muscles ought to have been applied at a very great Distance from the Center of Motion, and a fixed Point must have been placed out of the Body, which must therefore have been like a Tower composed of many large Machines; but to avoid this Inconvenience, the Creator did not make use of the mechanical Advantages, as they are supposed to be by Man; but having a full View of his Defign, and of the Effect to be produced, he has providently disposed every thing to answer its Office with the least Disadvantages, insomuch that one may very wn

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well admire (200,465 street TOV Stov) the Geometry of God, which are the excellent Words of Plato.

- §. 411. But in what manner the Nerves can derive so great Forces to the Muscles, can be only demonstrated from Hydraulics and Hydrostatics explained by Mariot.
- The Increase of a Force is almost infinite, which arises from the moving Power applied thro' a small Tube to a large Receptacle intended to be moved. This entertaining Phænomenon was first demonstrated by Mariot, a Person born to promote philosophical Knowledge. I tried an Experiment with the Machine made by Muschenbroeck; it was a cubical Ciftern made on all Sides with the strongest Plate Iron, upon the upper Part of which was fixed a fquare flexible Plate of Copper: and upon filling this Ciftern with Water, while to one Side was fastened a very long Glass Tube, like that used for a Barometer; and letting out the Air which yet remained in the Machine, by means of a fmall Aperture furnished with a Valve, he placed so great a Weight upon the Lid of the Ciftern, as bent the Copper Plate inward, and then upon pouring one Ounce or two of Water into the Tube, while the Ciftern contained fifty Pounds, the flexible Lid of the Ciftern was by that means lifted up, together with a hundred Pounds Weight, fo foon as the Water was a little higher in the Tube than in the Ciftern. And if a Tube was to be adapted a thousand time longer, it would easily raise a thousand times the Weight, so that I could fafely undertake to raise the whole Stadt-House or Exchange of Amsterdam with one single Ounce of Water. For when the Water descends through the Tube one Foot, it raises the flexible Lid through R . 3

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fo much a less Space, as the Area of one Foot of the Tube is less than a Foot of the Area of the Ciftern, and therefore the Space run through by the Water makes up for the Smallness of its Weight. It is certain that Machines of the greatest Force may be broke by pouring in a fmall Quantity of Water, as once happened in my own House, when the Water being froze in a strong Cistern inclosed within the Walls, the whole Side of the House and Walls were raised by the Force of Water, which ran from the Top of the House through a Pipe in. to the same Cistern, which being froze could not vent itself. I afterwards avoided the like Inconvenience by making a lateral Opening in the Gutter or Pipe to evacuate the Water which came from the Roof; and hence it is usual for Builders when they fortify Cifterns, to leave an artificial Opening to the descending Water. We see therefore what a confiderable Force may be exerted by a small Quantity of Water, fo as to overcome almost an immense Weight. But the same Experiment may be also tried another Way. Take a Hog's Bladder almost empty, hang it to a String, and let a strong Cord be tied round its Neck, conftringing it fo close round a Tobacco-pipe that no Air can pass betwixt; then let the Bladder, suspended by the String, be fastened to a Beam with a hundred Pounds Weight appended to its Bottom; then if a Child endeavours to inflate the Bladder through the Pipe with a small Force, the Bladder will be distended, and the Weight raised. But a greater Weight may be raifed by the same Breath, in proportion as the Bore of the Tube is of a smaller Diameter. If in this manner you repeat the Experiment, or fasten several Bladders to each other, a Child may raise above a thousand Bladders with the like Weight to a moderate Height. But this we

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find to be the Mechanism used by the Creator in the Fabric of the Muscles. A small Nerve is a little Tube, the Blast or Inflation is produced by the animal Spirits paffing through it, the Bladder is answered by the expanded Part of the hollow Fibre, the Weight to be raifed is the Bone, with all the other Refistances. Nor ought it to be objected, that the very small nervous Tubes would burst by such a Force: for the Force itself is very fmall, by which in the preceding Experiments the Water descends. Even in the Case mentioned, where the Foundation and Side of the House was elevated, the Pipe which conveyed the Water from the Roof was not at all injured; but when the fame Pipe was perforated in the Side, the Foundation subsided. This may be therefore sufficient to account for the wonderful Strength or Force exerted by the Muscles, and every way agreeable to the Circumstances mentioned at §. 406.

§. 412. But this Force 1 of a Muscle is directed by wonderful and mechanical Affiftances, fuch as, 1. Membranous 2 Swathes or ligamentary Fasciæ, which being broadly expanded, invest and confine together the subjacent Muscles and Tendons, as at the Carpus, and in the Foot. 2. Besides these ligamentary Fasciæ, there are also others more broad and muscular 3, as in the Arm 4, Back, and Thigh. 3. They are affifted by cartilaginous Pullies 5, as in the Trochlearis Muscle of the Eye; or elfe by bony Pullies, as in the Pterygostaphylini Muscles. 4. By one Muscle transmitting and directing another, as in the Styloceratobyoidei 6. 5. By Hypomochlia 7, or Props Props sustaining, directing, and raising the Tendons of the Muscles, as in the Patella of the Knee, the Ossa Sesamoidea at the Joints of the Fingers. 6. By broad Appendages 8 and Handles 9 growing out of the Bones, as in the Trochanters of the Thigh Bone. 7. By the winding round of the Muscle itself about the Bone 10, as in the Marsupialis or Obturator internus. 8. By Fat and mucilaginous Capsules 11, and Cases loosely investing the Muscles and Tendons, and always lubricated internally with an unctuous or fat Humour, by which the Motions of the Muscles are wonderfully affisted and quickened.

There have not been wanting impious Men, who have supposed that the immense Power exerted by the Muscles, was in a manner thrown away as useless, since the Weights might have been raised with a less Force in a different manner, whence they take occasion to accuse the wise Author of Nature: when at the same time they do not consider the great Wisdom by which the great Architect has avoided the Incumbrance of those vast Machines, by which only Men can increase mechanical Powers, the human Body being itself a Compendium of all manner of Machines most advantageously disposed.

It was necessary for the Uses of human Life, for the Hand not to be formed of one continued Part or Trunk, but of several distinct Bones variously articulated together, each of which might be moved by its proper Muscle. No Animal has that beautiful Fabrick of the Hand which we observe in Man, even Monkeys themselves not excepted. The Wrist is composed of eight Bones,

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the Metacarpus of five Bones, the Fingers of twelve, and the Thumb of two, besides some small Offa Sesamoidea. Each of these Bones are varioufly and beautifully articulated and fupplied each with their proper Muscles. But these Muscles could not well arise from those small Bones themfelves; for if fo, the Hand could not then have had fo large a Motion, nor would there have been any room for the Reception of fo large Muscles, as are required for its strong Motion; therefore the wife Creator has made the Muscles of the Hand both large and long, agreeable to the ample Motion it required; and yet he has not loaded the Hand itself with Flesh, but he has placed those Muscles uniformly about the Arm, continuing only their Tendons into the Bones of the Hand. But to prevent the Limb from fwelling too much, it was necessary for these Tendons to be inferted into the Bones, and for the Muscles and Tendons themselves to be continued in a right Line; and to preserve them in that Direction, we observe strong tendinous Ligaments placed at the Carpus and Tarfus, under which the Tendons pass, and are tied down in fuch a manner, that they cannot be displaced. These confining Ligaments are very well represented by Eustachius in the Carpus, Metacarpus, Fingers, Tarsus, &c. Nor is it necessary only for the Physiologists to be acquainted with these Tendons, but they ought also to be observed by the practical Physician, since the more frequent Cause of the Cramp, which is one of the most lamentable Species of Convulsions, proceeds from a displacing of the Tendons out of their proper Spheres. Hence the strongest Porters, who support themselves by continual and hard Labour, being troubled with the Cramp, relieve themselves by fastening a Leather Strap round the

the Tarfus and Carpus, in order to make up for the Weakness of the confining Ligaments, which are not sufficiently strong to keep down the Tendons of the Muscles in their violent Actions. But there are not only common Ligatures of this nature to bind together the Tendons of the Flexors and Extensors, but every individual Muscle is confined by its proper Ligament and Capsule, as is represented in the Tibialis and Peroneous Muscles

by Eustachius.

Part of the Fascia Lata, pass into membranous and tendinous Expansions, which ought to be rather called muscular Expansions than real Muscles. A Capsule of this nature descends from the deltoide Muscle round the Humerus and Cubitus, so as to invest all the Muscles of the whole Arm. But the Muscles of the Thigh are likewise invested with a tendinous Expansion, arising sleshy at the Glutei Muscles, and denominated the Fascia lata. But the Use of these Fascia is not to move the Articulations, but to contain and secure the sleshy Bodies of the larger Muscles in the same manner as the annular Ligaments keep down the Tendons.

It is from this Fascia that an Inflammation and Gangrene arises, after the Tendon of the Biceps Muscle of the Cubitus has been injured in Bleeding. And from hence the tendinous Expansion being injured in a Paronychea, which is continued to the little Finger, the Pain passes from thence with the other Symptoms even to the Shoulder. And from hence Wounds inflicted in the Knees, with Pains, Inflammations, Tumors, Ulcers and Gangrenes, extend themselves from thence even to the Edge of the Os Ilium, namely, these Disorders spread themselves as largely as the tendinous Expansion itself, which they injure.

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When any Weight is to be raifed heavier than the Person's Strength, (for Hercules himself cannot raise a Weight heavier than that of his own Body) or whenever a Body is to be fo regulated, as to pass from the Person who moves it, it is usual to twist a Rope round a Post, or some other firm Body, that the Direction of the fixed Point may be opposite to the Body which it antagonizes; and by this means very great Weights may be raifed. There is but one Instance in the human Body, in which the Limb is as it were to be moved out of the Body itself, as in the Tongue, Eye, It was necessary for the Eye to be capable of projecting out of its Orbit, as in beholding any thing horrid or frightful, and in amiable Affections turn'd inward towards the Nofe, which is also the Posture when we look at any thing with great Attention; and for this Purpose Nature has placed two Muscles of the Eye in such a manner, as to be capable of thrusting it more or less out. There is an annular Cartilage placed more forward, in the upper Edge of the Orbit, than the Globe of the Eve itself, from whence the Tendon passes, and is reflected back a fecond time; fo that when the Muscle contracts, it does not draw the Eye backward, but forward, or outward towards the Pully thro' which its Tendon passes. When such a Pully belonging to a Tendon labours under some Defect. a Palfy of the Muscle follows, which the Physician very often unjustly ascribes to the Muscle itself.

<sup>6</sup> The Digastric Muscle of the lower Jaw arises much higher than the Part of the Jaw itself into which it is inferted, and therefore it would naturally elevate the Jaw, if it was not for a particular Contrivance, by which its middle Tendon paffes through an Opening in the Stylohyoideus Muscle. much lower than the Chin, to which the Digastric

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from thence ascends; and thus the lower Jaw is pulled down towards the Os Hyoides. This Mechanism obtains in the Tendons of the Muscles of the Fingers and Toes, called Perforati and Perforantes.

By this Name we call the fixed Basis or Point which supports the moving Power, so that it may act; for Instance, suppose a thousand Pounds in Weight are to be raifed by the Force of one hundred and fifty Pounds, it is very evident that I cannot easily so much as stir such a Weight unless I place an Iron Lever under the Weight, to which the subjacent Earth is for a fixed Point; fo that by depressing one End of the Lever, I raise the Weight opposed to the other End. In the human Thigh there are vast large Muscles, the Rectus, the Vaftus Externus and Internus, which direct the Thigh in a right Line while they act; but these Muscles are placed fo much in the fame Direction with the Thigh itself, that they seem to have altogether no Force when the Power which draws the Lever in a parallel Course exerts no Force in elevating or depressing the same Lever; and the less the Angle of Direction is, so much more of the moving Power is loft, for Powers are as their Sines: hence we fee that the Patella is added to the Articulation of the Femur with the Tibia, that the fixed Point upon which the Motion is performed might be transferred fomewhat further, towards that Point to which the Leg is extended. Hence it is that the Patella being fractured, the Knee is perpetually loose and wavering, so that the Person cannot tread fure, and the Patient is obliged to supply the Defect with a fort of Patella made with Steel. The Offa Sefamoidea are Hypomochlia or Supports of this kind; and it is from these Bones frequently found in the Tendons of the flexor Muscles of the Fingers, that we frequently find that fome Men who have flender Fingers are nevertheless stronger than those who have thicker and feemingly stouter Fingers, that is, with larger Muscles; but we are not to estimate the Force of a Machine from its Magnitude but from its Structure. In the Hare which is one of the swiftest Animals, there is a Mechanism of this Kind, namely, a large Os Sesamoideum placed at the Back of the Foot over which the large Tendons pass as over a fixed Point, which Point of Motion or Hypomochlium is always larger in proportion as the Animal is swifter; but other Animals who are not so swift-footed are destitute of this Bone.

<sup>8</sup> The larger Bones have ample Epiphyses or Appendages at their Articulations, and to increase the Strength of each Joint their Heads are very broad, and the Motions of the Joints are always weaker in those Men who have the Epiphyses smaller and more even, as in those who live a monastic Life.

Number of Processes and Asperities, despising the minute Diligence of Anatomists who fatigue their Audience with enumerating the infinite Number of Processes and Sinus's or Foramina. But they make this Complaint very unjustly, for there is not the least Roughness or Inequality of a Bone which is destitute of its Use, or which does not contribute something to the Motion or Advantage of the Limb. The Thigh could never be moved round, or bent inward or outward, unless the Femur was surnished with those Processes which are called Trochanters from their turning round, as Borelli has very well demonstrated. Add to

this that the Rotator Muscles insert their Tendons

into the protuberant Process.

10 There was no other Place where the Rotators of the Thigh could be fixed, which draw it partly outwards. They certainly could not be placed without the Body, and therefore the Pelvis is furprifingly perforated that the Muscle itself may pass through a Foramen, and wind round the Femur. by which means the Rotator can turn it outwards. while at the same time the Reflection of the Muscle gives it an Opportunity to be almost three times as large as could have been in a direct Courfe; and thus both the Force is increased and the Direction obtained which the Nature and Use of the Part required. It is a childish Opinion that these Muscles are formed merely to stop up the Aperture, for the Creator could as well have made it a continued Bone, if this Muscle had not been necessary to be feated in that Place.

There is no Muscle which immediately touches the other Muscles to which it is adjacent, but every one is invested with a cellular Membrane replenished with Fat; and even there are not any two Fibres of a Muscle, but what are surrounded with the adipose Membrane; nor is there any Tendon, but what is likewise invested with the same Membrane continued from the fleshy Body of the Muscle even unto where the Tendon itself is inserted into the Bone. These investing Membranes are very thick and full of Fat about the larger Mufcles, as for Instance, the Glutei, pectoral, and vasti Muscles, not excepting those that are less, which are likewise surrounded with the cellular Membrane, though not fo much replenished with Fat as it is about the larger Muscles. About the Tendons the Fat in this Membrane is rather watery and mucous than fincere Fat, and the Tendons

move

move in the midst of it like Cords included in an oily Case. If the adipose Cells are destroyed, whether this happens in the Muscle itself, or in the Tendon, by a Burn or any other Accident, fo as to deftroy the pinguedinous Capfule of the Tendon under the Skin, an Immobility of that Muscle and Part certainly follows, or the Tendon infeparably coheres to the Skin. For it is owing entirely to the adipose Fabric, that one Fibre is moveable over another; but if by a Suppuration that Fat is destroyed which was interposed betwixt the Tendon and the Bone, in that Case the Tendons cohere even to the Bones, as we fometimes fee in Surgeons ought therefore to be cauthe Fingers. tious in confuming the adipose Membrane too abundantly by Suppuration, especially that which is feated about the Capfules of the Tendons, left they should occasion the Tendons to cohere to the Skin, Bones, or other adjacent Parts.

§. 413. But the attractive Force of the Muscles is very much increased, in proportion as the larger Muscle is made up of many fmaller ones joined together into one stronger Tendon, in which their Forces conspire; as, for Instance, in the deltoide 1 Muscle, the pectoral2, the Biceps of the Humerus, and the Triceps of the Thigh; for the more numerous 3 the Fibres, the stronger the Muscle; and the longer the Fibres, the more readily and largely 4 do they bend the Joint, while the transverse 5 smaller Fibres add much to the Constancy and Strength of their Motion, by confining and supporting them together in their proper Situations. This This is one of the strongest Muscles, and divisible into twelve distinct smaller Muscles; each of which are again distinguishable into others still smaller, and these again each into twelve smaller.

I must here add an Instance of surprising Strength. A Lion seized upon a Dutchman, jumping upon his Shoulders behind him; but the Man courageously clapp'd his Hand behind him, and squeezed the Throat of the wild Beast in such a manner, that by stopping his Breath all his Strength failed. This Muscle is also like the former, com-

posed of many fmaller ones.

3 Those Muscles which are the strongest are alfo the thickest and shortest, that a greater Number of Fibres might be contained together in the fame Space. For one Veficle is weak, and acts with a small Force, as, for Instance, with half a Grain; but when many thousands of these are collected together, they can raise many Pounds Weight. For Instance, in the Masseter, by whose Efficacy in a Turk Vefalius relates, that an Iron Crow was taken up betwixt his Teeth, and flung with fuch a Force over his Head, that it stuck into the Wall trembling. In the Lion almost the whole Head is nothing but Maffeter Muscles, and the whole Scull is in a manner preffed into a Ridge or Spine, so as to contain internally but a few Ounces of Brain. But these Muscles are but short, fince the Distance that the Jaw is to be raised scarce exceeds half an Inch, and therefore short Fibres were sufficient for this Action, which are upon that account stronger. The Heart itself is also composed of Fibres equally short, whose Forces are almost incredible.

<sup>4</sup> The longer the Muscle, the larger is its Motion; but then it is so much the weaker. Bernoulli has demonstrated, that a hollow Fibre can-

not be farther diftended by the Ingress of the neryous Fluid, than to be contracted one third Part of its Length. Nor is this difficult to demonstrate: for a collapsed Bladder cannot be distended into any more capacious Figure than that of a Sphere; fo that if the Thickness of a Bladder was nothing before, after Inflation it will be equal to its Diameter. But the Diameter is one third Part of the Circumference; and therefore when a Muscle loses in Length, it gains as much in Breadth; that is, one third Part being lost in Length, will be gained in the Diameter or Thickness. Since then the Proportion is but short in which the muscular Fibres can be diminished in Length, there are therefore long Muscles for performing ample or large Motions of the Joints, in which Muscles the Diminution of a third Part of their Length will make a great Difference betwixt the Flection and Extension of the Limb. Thus the Motion of the Arms is ample, and therefore the Biceps or Flexor is very long, by which a Motion may be produced answerable, which it could not have been by a short Muscle.

Long Muscles very easily start out of their Places; to prevent which, their long Fibres are collected together by small or transverse ones, which bind together their Fasciculi, being frequently tendinous and very conspicuous in the Recti Muscles of the Abdomen.

§. 414. The Action of any fingle Muscle may be easily known, if we are acquainted with its Connection, Course, or Direction, and Degree of Mobility in the Parts to which the Tendons are connected.

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In order to determine the Action of any Muscle, we are to examine into its Origin and Insertion, with the Resistance or Mobility of the two Parts to which it is attached; from whence the Action will be given; and the Motion of the Parts to be inslected, will be in an inversed Ratio to the Resistances. As for Example: If the Bones A and B are drawn by the same Muscle, and the Resistance of A is as 3, and that of B as 2; in that Case the Bone A will be drawn towards B with two Parts of Motion, while B will approach towards A with three Parts.

I have frequently observed with Wonder, that Philosophers and Physicians should so minutely determine the latent Powers of Muscles, when there are so many things to be considered, as render it extremely difficult. In the Marsupialis Muscle, the interposed Hypomochlion alters both the Direction, the Power, and the Action of the Muscle, resembling a Cord passing round a Pully, and returning in a contrary Direction.

§. 415. Therefore the voluntary Muscles have Nerves, which arise ultimately from the Brain.

But the involuntary Muscles which act fpontaneously, and are employed in the vital Motions, receive their Nerves from the Cerebellum<sup>2</sup>.

The innate Motion 3 remaining in the Fibres after Death, depends upon the spontaneous 4 or involuntary Contraction of their Fibres and Vessels.

Nor does the Contraction of a Muscle by any means proceed from their spontaneous Tension Tension or Elasticity, or from the Contraction of their Nerves 5.

Although the nervous Juice has a strong Action upon the Muscle, yet it does not injure 6 the small Tubes through which it passes, as is evident from hydraulic Experiments.

A Muscle kept too long 7 in a violent Contraction, grows painful, becomes inflamed, and mortifies; the Reason of which is evident from what has been already said, and the Truth of it appears from Experiment in a Tetanos.

Muscles alternately contracted and relaxed, do likewise reciprocally admit and expel their Blood with a considerable Force 8.

The Blood is therefore attenuated, ground together, and dissolved 9, as well in the Muscles as in the Lungs 10; and therefore the Actions of the Muscles may, in some measure, often supply the Desect of the Action of the Lungs.

From hence we may judge, why a stirring; active 11 and brisk Life has different Effects upon the Body, in comparison with those Effects that follow from a sedentary and solitary Life.

By too much Rest or Inactivity in healthy Bodies, the accumulated Oil 12 compresses and diminishes the Capacity of the Fibres and Vessels; whereas an Animal which has been addicted to too much Exercise, grows thin and lean 13.

Old

## 260 Action of the Muscles. § 415.

Old Age and a laborious Life almost change the Muscles at length into Tendons 14, the Tendons into Cartilages, and the Cartilages into Bones.

Lastly, That there are many hollow 15 Muscles in the Body; the venous Sinus's, the Auricles and Ventricles of the Heart, the Stomach, Intestines, Bladder, &c.

Since if this Viscus remains entire, while there is no Injury offered to the Nerves or Muscles, all the voluntary Motions are then regularly performed: but when the Brain is corrupted, or labours under some other Defect, yet the Muscles cannot perform their voluntary Motions, even though themselves and the Nerves remain uninjured, as evidently appears in an Apoplexy arising only from a Compression of the Brain, as Wepfer has demonstrated by numberless Observations.

when the Cerebellum alone is compressed, all the Limbs, Muscles and Viscera throughout the whole Body suddenly lose their Action, even tho the Brain itself remains entire, and without Injury. But when the Brain only is rendered useless by a Compressure of its Ventricles, while the Cerebellum remains uninjured; in that Case all the animal Faculties of Sensation and voluntary Motion are destroyed, and yet Life is continued for a considerable time after.

For this Force is increased after Death, when the solid Parts of the Body are more violently contracted by the Cold: but when the Cold is too intense, these spontaneous Motions are very small, being almost totally abolished. In the most intense Cold, the pectoral Muscle of the Arm can scarce move that Limb the Breadth of a Line to-

wards

posible

wards the Breast, though it performs one of the strongest and most ample Motions, while it was warm and well. Glisson does not therefore make a reasonable Proposition, when he says that the Muscles act by a Force seated in themselves; but which Force is more rightly taught by Bellini to be superadded to the Muscles from without themselves.

4 In a strangled Animal, which has lately expired by hanging with a Cord, we fometimes obferve a Muscle suddenly moves, and continues its Motion for fome time. The fame happens if the antagonist Muscle is cut out; and the same also if a warm Liquor is injected into the Artery of the Muscle, for by both of those Methods it will be contracted. Now the Cause of these Motions, which happen after the Death of the Animal, is almost entirely the cold, by which the external Parts that are most exposed are strongly contracted, and by that means their contained Humours are propelled towards the internal Parts, which are not yet destitute of their vital Warmth; from whence they are again repelled, fo as to produce fome Motions of the Muscles like those made by the Influence of the Will.

There are some Physicians who teach that the Nerves act by a vibratory or tremulous Motion, which they receive from their Origin and communicate to the Muscles, which are by that means put into a similar tremulous Motion; and that from hence arises the Contraction of the Muscles. But we have demonstrated in another Place (§. 284.), that the Nature and Action of the Muscles is very different from that of a tremulous Chord, fince the Nerves are neither tense, nor extended in right Lines, free from contiguous Bodies, as is necessary for the Vibrations of musical Chords; nor is it

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possible thus to explain their Action, on Account of their many Angles and Inflections, without admitting some accessory Fluid; notwithstanding a like Explication was attempted by Steno, namely, that all the Fibres of a Muscle do with their Tendons form oblique angled Parallelograms: and that in the muscular Contraction the Fibres are drawn towards their Origin, change their Angles into more obtuse ones, so as to acquire a shorter and fquarer Figure, by which means as much is diminished from their Length as is added to their Thus did this Anatomist Breadth and Thickness. think he had accounted for all the Appearances of Motion in the Muscles, by which they are evidently contracted or shortened. But he did not consider another Theorem in Mathematics, that among Parallelograms, a Square is the most capacious, and that the more equal the terminating Lines of a Figure are to each other, the more Space do they contain or circumscribe; but that their Capacity is continually lefs, as any two of the four parallel Lines are longer than the rest. Had that Anatomist remembered this Theorem, he would easily have feen from his own Hypothesis, that to render a Parallelogram shorter required a new Accession of Matter to fill up the increased Capacity of the Figure.

6 This is evident in the Tobacco-pipe by which a Bladder is inflated so as to raise a Weight of a hundred Pounds. A certain Physician objecting against my Opinion in this respect, occasioned me to make the Machine mentioned (§. 411); but in the Experiment with this Machine he plainly saw that the Lid was raised with a great Force without breaking the very brittle Tube through which

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the Water descended.

7 If we use any Muscle too long in walking, carrying any thing, or any other kind of Labour, that Muscle becomes extremely painful and weak, infomuch that we rather wish for Death, than to continue the Muscle longer in the same Action. The Cramp and Tetanos of the ancient Physicians. is a Diforder in which the Muscle continues too long in a State of Contraction contrary to the Inclination of the Mind; but if the Muscle continues too long a time in that manner contracted, a Mortification of it foon follows, or even if it is relaxed before, yet a Pain and flight Inflammation will continue in the Muscle for some Hours after. The Reason of which Consequences is, that the muscular Fibres being very turgid with the nervous Juice, repel and exclude all that Blood which was usually brought into the larger and smaller Arteries of the Muscle; so that the whole Vis Vitæ acts with its Force intirely upon that Part of the Artery which is compressed; whence arises a violent Attrition of the Humours in that Part of the Artery, those Parts only are transmitted which are more fluid, while the rest are compacted into impervious Masses, so as to generate a true Inflammation, and the smallest Vessels themselves having their Elasticity and Continuity overcome, are broke or divided by the Force of the impacted Humours. But if again the Force by which a Muscle is drawn into Contraction has been too long continued, and the Person endeavours to relax the same, the Motion of the Blood through the Veffels of the Muscle will be little or nothing easier than before; so that its Course through the Vessels will be intercepted, and then fuch a Muscle will mortify. By Accident a Man fell into the Water, who being ignorant of the Art of Swimming was faved by putting out a long Pole for him to take hold of, which he S 4

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Life, that when he endeavoured to let it go out of his Hand, he was not able; for the extensor Muscles were not capable of overcoming the Power of those Muscles which had been too long contracted: Hence it is that provident Nature has made it necessary for the Muscles to be alternately relaxed as well as contracted; the Heart itself with the Sinus's and Auricles, the Arteries and Muscles of Respiration are thus alternately relaxed after they have been contracted; and the peristaltic Motion continues in a Succession, being transferred from one Point to the other, so that the Motion ceases in one Part while it is renewed in

the fucceeding (§. 93.).

When the Fibres of any Muscle are contracted, then the Arteries and Veins (§. 406.) which pass betwixt the turgid Fibres, are compressed and obstructed, the Blood which they have already received is expelled from the smaller Veins into the returning Trunk, while the Entrance of the Blood is refisted in the Artery above the Muscle. When the Muscle relaxes itself after Contraction, then the Blood which was excluded and accumulated at the Entrance of the Muscle, is swiftly propelled with a confiderable Force from the Heart and Arteries, fo as to pass into the Veins of the same Muscle, with a Velocity increased in proportion as the Refistances of the empty Vessels was diminished. Thus we fee in the Heart that after its Contraction the Paleness is suddenly succeeded with a Redness throughout every Point, as if the Heart derived the venal Blood into itself from the Lungs and all other Parts of the Body. But there is yet another Cause why the Blood passes more swiftly through a moving Muscle, namely, that as we have frequently observed the Vein is emptied in the

the contracted Muscle, and by that means readily receives the Blood with a rapid Motion, which was before accumulated and in waiting in order to pass through the Muscle. It has been also demonstrated by the Royal Society, that Water and Air rush into an exhausted Receiver with a Velocity twenty times

greater than that of the fwiftest Wind.

before it enters the acting Muscle, is compressed into a small Compass by the Impulse of the succeeding Blood, so as to form in some measure a kind of Instammation; but when the same Blood is let free from its compressed State into the open Vein which gives no Resistance, the Blood will by that means be three times more highly attenuated, and its Globules will recede in Proportion from their mutual Contacts.

on, the venal Blood is carried with a swift Motion from all the pulmonary Veins into the lest Sinus: but the very next Moment after this the Blood of the pulmonary Arteries rushes into the empty Veins, by which it rarefies and is resolved or attenuated by diminishing the mutual Contacts of its Particles. But all this holds equally true with respect to the Course and Attenuation of the Blood

through the moving Muscles.

who neglect their Bodies to improve their Minds, are subject to continual Disorders. For in People who live a sedentary and solitary Life, the Blood is only attenuated by the Lungs: but in these even the Lungs themselves perform their Office more sluggishly, since the other Muscles do not urge them on to act, by accelerating the Return of the venal Blood; and therefore in these People, this last and principal Organ in which the Blood is at-

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tenuated is very much impaired. Hence that Thickness and impervious Nature of the Blood, by which it is apt to stagnate in the smaller Vessels. and from whence arises the detestable Train of hypochondriacal Diforders. But Strength and Activity of the Muscles judiciously exercised, produces the contrary of all these Disorders. For the moving Muscles impel more Blood in a given time to the Lungs, by accelerating its Course through the Veins; and therefore by exercifing the Muscles, the Lungs themselves are excited to a greater Efficacy in attenuating the Blood. Besides this, the Muscles themselves also dissolve and perfect the Blood, and in a manner perform the same Action upon it with the Lungs; fo that a double Advantage arises from Exercise, namely, an Increase of the Efficacy of the Lungs with the like Action of the Muscles themselves. It ought therefore to be a principal Rule with those who study Knowledge, the Truth of which I have experienced many Years ago, to wit, never to fet themselves down to Dinner or Supper, unless they have first used some moderate Exercise for the Space of an Hour, which was formerly the prudent Advice of Leonidas. But yet I would advise the Exercise of Body to be moderate, and not too violent; for Horfes exercifed with too fudden and violent Labour, foon perish.

<sup>12</sup> All People are conftantly nourished with Milk or Chyle, however various may their Diet be, which is a white, uniform Juice prepared by the vital Powers from the Aliments. But a large and principal Part of Milk is Cream, which being preffed together forms a fat Oil or Butter; and therefore as the Blood is formed out of Milk, a confiderable Portion of it will be a true Oil. But all Oil is tenacious, or very difficultly continues

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the Motion which it first received, and therefore it is repelled by any watery Liquor in which it fwims; fo that if it be forced together with Water through a Syphon, it follows flowly after the Water in an interrupted and fluggish Course with a great deal of Reluctance, inclining towards the Sides of the Tube. In the fame manner therefore will the oily Parts of the Blood hesitate, unless attenuated and urged on through the small Vessels by the Motion of the Muscles; and from hence it will be deposited out of the lateral Arteries into the Cells, where it will be perpetually accumulated, till almost the whole Animal is buried in Oil or Fat; for while the Animal is at Reft, the Oil is perpetually fecerned from the Arteries, without any Part of it being returned by the Pressure of the Muscles into the Veins. But when the oily Cells are turgid, they compress the adjacent Vesfels by degrees in proportion as they are more distended; and therefore there is less Blood in a Perfon, in proportion as there is more Oil or Fat. 1 am indeed not ignorant, that the common People, and even many Physicians, are persuaded so strongly to the contrary, that you can never induce them to believe, that a Man who appears large or corpulent with Fat, contains less Blood than a Person who is more thin and lean: but we are certain that every Animal grows fooner fat, in proportion as it has loft more Blood, provided the Animal continues in Health; and therefore it is a common Practice with Farmers to bleed their Cattle, in order to haften their fattening. Women who lofe a confiderable Portion of the Blood monthly, are in the general observed to be fatter than Men: and Animals are not only fattened in a short time by repeated bleeding, but even other profuse Evacuations of the Humours produce the same Effect.

Those who have been subject to the repeated Use of Purges for a long time in obstinate Gonorrhæa's. and those who have lost a great Part of their Juices by a mercurial Salivation, fo as to melt down and expel almost all their Fat, do from an emaciated State very eafily recover a greater Degree of Fatness, after the Person has recover'd his Health. Swine, who are perpetually confined in a narrow Stye, are buried in Fat, so as to be at length suf-Quatit Tussis anhela sues & faucibus angit obesis. A Countryman made an Experiment to how great a Degree an Animal might be fattened; and the Animal which I faw weighed feveral hundred Pounds, being almost entirely nothing but Lard: the Viscera themselves were compressed into a very little Compass, and there were only some few Threads of muscular Fibres left of the Muscles, which appeared red in the midst of the Lard. The Person who has his Blood-vessels very large in a lean State, will have them three times fmaller and scarce visible upon growing fat; nor are the Veffels therefore more numerous in a fat than in a lean Person. On the other hand, the Motion of the Muscles dissolves the Fat, renders a Person lean, and increases the Mass of Blood into which the Oil is returned through the Veins. The commendable Medium therefore feems to be for us to use fo much Exercise, as to be never stuffed up with Fat; and yet not to labour to fuch a Degree, as to render the Bones and Muscles conspicuous through the Skin, that is, to become too lean.

All that has been faid concerning the Motion of the Blood from an external Cause, namely, the Motion of the Muscles with regard to Fatness, the same is also true when the Blood's Motion is increased by a Fever. For by both these Ways the Oil or Fat is attenuated, mixed with aqueous Hu-

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mours; and after becoming rank or acrid, it is at length evacuated in Sweats or Urine which have a strong Smell, while at the same time the Salts are more exalted or sharpened, and the whole Body emaciated and confumed. If you have a Horse who has been out to Grass all the Winter, and defire to bring him to Strength and Labour, exercife him prudently by degrees, every Day more and more in the returning Spring; and thus he will acquire a State of Health, and be capable of using his Blood and Muscles in the swiftest Courses without Damage; and thus you may exercise him till he appears to be nothing but Skin and Bones, notwithstanding he continues in a healthy State; whereas if such a Horse was at first to be suddenly used with hard riding, it would soon kill him. A certain Hare being made wife or cautious by dangerous Experience, after having exercifed the Hounds and Huntsman for many Hours in the scorching Sun, at length takes Refuge in the Farmer's Stable, being no longer able to continue the Flight; but unfortunately the Veffel happens to be wrecked in the Harbour, for the Countryman in stirring up the Straw seizes the Refugee, and finds the whole Skin quite black from the Turgescence of its Blood-vessels, infomuch that the Animal must have perished in a little time, merely from the Swiftness and Continuance of its Course, which obliged it to rest.

The Flesh of the plowing Ox that has been used to hard Labour, is so tough, and in a manner cartilaginous, that no Persons can well divide it betwixt their Teeth. Even the Cock, who was a few Years ago so tender a Fowl, becomes at length seeble, and the Muscles and Tendons of his Legs become bony, and those of every other Part proportionably tough. The muscular Fibres of the

Stag,

Stag, which has been fatigued by chasing, are juiceless, and almost like those of Wood, while Part of the Heart itself is converted into a real Bone, not without considerable Detriment to the Animal; which Bone is what the Arabian Physicians recommend to prolong Life. In a very old Man, who has been perpetually addicted to Labour, the Muscles of the Back, namely, the Semifpinalis, Longiffimus and Sacrolumbalis scarcely retain the Nature of a Muscle, but become indurated like the Tendons of the Bones; while the Bones themselves become hardened and more compact than they naturally ought to be, as is evident from the disappearing of the Sutures, so frequently observed in the Skulls of old People. At the same time also the Tendon in the Septum of the Heart itself begins to turn into Bone, and so does likewise the Beginning of the Aorta and pulmonary Artery by degrees acquire a cartilaginous Nature. Willis also observes, that the jugular Veins and their larger Sinus's become indurated in this Manner; and if Age continues, the carotid Arteries themselves, and then the falciform Sinus of the Dura Mater offify. From hence therefore it appears, that barely by muscular Motion continually and immoderately used, all the smallest Vessels are first rendered impervious, and afterwards quite obliterated or turned into compact Fibres. that Cause of Immobility which arises from too much Rest or want of Exercise is of a very different and opposite Nature, notwithstanding they both produce the fame Effect. We have frequently observed Men who having broke their Arm have been commanded to perpetual Rest by their unskilful Surgeon, the Limb in the mean time being kept immoveable and in the same Posture for the Space of fix Weeks, when he briskly removes the Dreffings with high Expectations of his Reward, but unluckily he finds the whole Arm immoveable. The conftituent Particles or Elements of our nervous Fibres feem to be of that Nature, that if the Fibres continue too long without being expanded by the Impulse which the Spirits make in their Contraction, the Elements by that means acquire too great a Cohesion, whereby they become disobedient to that Force by which they were before contracted, whence their Motion is at length utterly destroyed. But by an alternate Exercise and Rest, the Strength of the solid Elements, as well as their due Mobility or contractive Nature, is preserved at the same time, so as to render the Muscles as active as possible.

The Heart, Auricles, and venous Sinus's, the Sinus of the Vena Portæ, all the Arteries, the Stomach, Intestines, Pelvis of the Kidney, Ureters, urinary Bladder, Uterus, &c. are all hollow Muscles, and receive their Nerves from the Cerebellum, and are not subservient to the Influence of the Will.

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## The Function of the Skin.

ALL the Muscles 2 of the Body are covered under the Skin with a thin cellular Membrane, furnished with Arteries 3, Veins, Nerves, lymphatic Vessels, and oily Cells 4, as also with some muscular Fibres distributed here and there through its Substance, to render its Fabric the more capable of receiving and expelling the oily Part

of the Blood. This Membrane is extremely dilatable 5, infomuch that it may be enlarged almost to any Bulk; its chief Office being to collect the Fat, which is yet only a thin Oil6 stagnating in the round? Cells of this Membrane. This oily Fat being separated by a slow Motion of the Blood passing from the small Arteries opening into the contiguous Cells, ferves to defend, lubricate, and anoint the Muscles, which are not only each of them furnished with a Membrane of this Substance, by which they are distinguished from each other; but also the same cellular Substance, intermixing itself betwixt the Fibres 8 of the Muscles, separates each of them from the other: but its contained Oil not only serves to facilitate the Motions of the Muscles and their Fibres, but also by returning into the Blood, it serves to temperate the Acrimony 9 of all the Juices, and prevents the bad Consequences which might arise from a too violent Motion of the Blood, as well as of the Muscles themfelves; and when this Oil has been dissolved by Heat and Motion, it may by Pressure enter into the small adipose Veins, and by them pass to those Parts where it is wanted, so as to mix with the venal 10 Blood in a more subtilized State; it may be questioned whether it does not exhale after having performed its Office? But we are certain that the Skin and Cuticle are moistened with an oily and unctuous Substance like Fat.

The Creator has determined the particular Bounds of the human Body, which it can exceed either not at all or but a very little. Internally the Magnitude of the Body is limited by the Bones; while externally its Bulk is determined in a great measure by the Fat, which varying in its Quantity required to be restrained within Bounds by the Skin, being one principal Office of that common Integument, which is of all others in the human Body the most tough and compact. But it was necessary for the Skin to be so formed as to discharge the Matter of Sweat, with the oily or sebaceous Matter, and to be freely perspirable as well as to form the Organ of Touch. To perform all these Offices it was necessary for the Skin to be furnished with Nerves and Vessels of divers Kinds. These Veffels are covered externally with a Cuticle in fuch a manner that there is not one Papilla of a Nerve nor any fingle Vascule exposed nakedly to the Air. But the Skin not only discharges Vapours externally, but it also inspires moist Vapours which it attracts from the Air. I am perfuaded that as there are daily five Pounds of Moisture discharged from the Body in a Day by infensible Perspiration, fo on the other hand there is a large Quantity of moist Vapours absorbed which are taken in by infensible Inspiration, not in a much less Proportion than that of the expirable Vapours. A very wife Physician who attended the Health of the Prince De Montecuculi at Vienna, related to me an extraordinrry Case of a dropsical Woman who though she took little or no Drink had nevertheless a daily Increase of the Water, and discharged large Quantities by Urine. As the Reason of this Appearance was obscure, the Emperor ordered watches to be fet by the Woman that there might be no Fraud in the Case by giving the Woman any Drink privately ;

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ly; but it appeared that there was no Deceit in the Case. If we admit absorbing Veins there will not appear any thing furprising in this Event: for we may eafily conceive more Moisture to have been absorbed from the Air by the Veins than was discharged by the Arteries. And hence we have a Reason why we become thirsty in dry Weather, and require little Drink when the Air is moift; namely, for that though we equally perspire, yet in a dry Air less Moisture is absorbed. whereas in a moift Air there is a much larger Quantity of Humidity taken in. Therefore San-Etorius does not appear to have determined the whole Measure of the perspired Moisture, since he deduced his five Pounds only from the Weight of the Aliments which were taken into the Body; whereas the Proportion of the perspirable Matter may be much larger upon the Account of what is absorbed; insomuch that if he had added the Quantity of Moisture absorbed to that which is expired from the Aliments, he might doubtless have brought the Proportion of perspirable Matter to be to the Meat and Drink as ten to eight. Nor is it difficult to account for the extraordinary Increase of the Water in the dropsical Woman of Vienna, if you consider that the bibulous Veins never cease from their Office, whereas the Arteries may be fo weakened by a Deficiency in the Vis Vitæ as not to be capable of perspiring as much as the Veins absorb; and thus a Body may become dropfical even under the drieft Course of Food.

The Muscles are not covered with any common Integument besides that of the Panniculus Adiposus, that is, not with a common muscular Membrane investing all the Muscles under the Skin; but the cellular Membrane not only covers the Muscles externally under the Skin, but is also infinuated

infinuated betwixt every particular Muscle, and even betwixt every one of the Fasciculi of their Fibres as well as between every individual Fibre itself down to the smallest.

3 Ruysch demonstrates that Part of the Skin and Fat which lies next to the Muscles to be one continued Net-work of Arteries and Veins, besides which nothing else can be observed in emaciated Bodies. If you inject Water into the Veffels of the Skin, so as perfectly to wash out the Blood, and then inject those Vessels with Wax, you will be furprized to find what a Number of Veffels are fupplied to the Skin from the cellular Membrane, which is expanded beneath; that is, by filling all the cutaneous Arteries and Veins as well as those

of the cellular Membrane itself.

 The smallest sanguiferous Arteries and Veins communicate with the oily Cells, which again open laterally into the adjacent Cells, into which the oily Part of the Blood is deposited, as it passes through all the small Arteries, and cannot find a ready Entrance into the Veins; but creeping along the Sides of the Arteries, it flips into the lateral Ducts or Mouths of the Cells, where it is continually accumulated to a confiderable Quantity. For even supposing but one Particle of Oil, equal to the hundredth Part of a Grain, to be daily deposited in the cellular Membrane, it may by that means be expanded in a few Days to an immense Bulk; but if a Humour thinner than Oil passes into these Cells, it may be easily pressed out again into the Arteries, and be from thence conveyed into the Veins. In lean Animals there is little or no Oil found in these Cells. If a Hog is killed early in the Spring without having been fed, he will be found fo lean and poor, that the red Muscles will lie close to the Skin: but if you confine the Ani-T 2

mal, and kill him in the Autumn following after fattening, you will then find an Interval of Fat fometimes to the Thickness of a Hand's Breadth. interposed betwixt the Skin and the Muscles, in which neither Arteries nor Veins can be perceived. being a mere Oil collected in the Cells. From these Cells it is that the adipose Membrane has ac-

quired the Name of Cellular.

Hence it is, that by Inflation into this Membrane the Bulk of the Animal may be increased to almost three times its usual Dimensions: but then the Flatus is to be impelled either in the Forehead or in the Scrotum, where there is but little Fat. Several Physicians have made Experiments by inflating all Parts of this Membrane in Animals. excepting only in the Palms of the Hands and Soles of the Feet, where the Cells of the Membrane are too tough or tendinous to give way to the Flatus. I have fometimes observed the Eyelids diftended in the Small-Pox by the Inflation of this Membrane to the Thickness of two Fingers Breadth, the Tumor appearing pellucid. I saw a calculous Patient fo fat, that the adipose Membrane was fix Inches thick at the Navel, and the Kidneys themselves were compressed by the Fat, which was one principal Cause of the Stone in them.

The Galenists distinguish betwixt Sevum and Adeps, the latter of which only they admit in the human Body; but it is certain, that only the Horse and human Species have that kind of Fat which is a fluid Oil, and which after Death becomes a little more confiftent.

7 That the Cells have a round Figure, we learn from the Distention of them by any tenacious Matter, as in the Fat of Swine, which have the Difease properly termed the Measles; that is, when a more

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a more thick gelatinous Liquor is deposited and inspissated in the Cells, instead of the more sluid Oil: Besides this, if a Portion of this Membrane be instated and dried in such a manner that the Cells may be able to support themselves from collapsing, upon viewing them with a Microscope, you will perceive round Cells, like the Honey-bladders in Bees.

Beven there is not one single moving Fibre defitiute of its oily Covering. The Heart itself is often buried in Fat, and the Beginning of the principal Arteries are also invested with the adipose Membrane. But where the Muscles are smaller, this Membrane is thinner: so that in the Forehead, Occiput, Scrotum, Face, Hands and Feet, there is very little Fat, in proportion to the thin muscular Expansions which are there seated; but in the Arm, Thigh, Abdomen, &c. the Muscles are strong, and invested with a large Quantity of Fat or Oil, serving to lubricate the Fibres, and prevent them from drying.

Fifty Pounds of Fat have been observed to be

wafted in a short Space of time by a Fever.

10 There are an infinite Number of Experiments, which demonstrate this Communication betwixt the Cells and the Veins. If a fat Horse be immediately taken out of the Stable after a long time of Idleness, and gradually addicted to more Labour every Day, he may within the Space of three Weeks be reduced to fuch a State of Leanness, that the Skin will adhere to the Bones; and again, if the fame Horse stands idle all the Winter, he will recover his former Fatness. But when the Vis Vitæ is fo weak as to be scarce able to propel the Humours forward through the Veffels, then the Blood abounds more with Water than Oil; which Water escapes into the empty Cells of the T 3 emaciated

emaciated Animal, fo as to diftend the Cells which invest the Muscles, and produce a Leucophlegmatia, and as much of this Water is accumulated in the cellular Membrane under the Skin, as we sometimes observe of Fat; for in the Anasarca, the Muscles themselves never receive the Water, but the cellular Membrane only, which is spread betwixt the Muscles and the Skin. But the Cells of this Membrane, where ever feated, have all of them a Communication with each other throughout the whole Body. Take the following Experiments, from whence you may believe the Truth of this Communication. In the Memoirs of the Academy of Sciences, Anno 1713, there is an Instance of a Man, who by a Fall broke several of his Ribs, which wounded the incumbent Parts fo as to admit the Air into the Cavity of the Thorax: but upon the next Day the whole Skin of the Body appeared inflated, except the Palms of the Hands, and Soles of the Feet. In the History of an uncommon Disease which I published, there is an Instance of a Rupture in the Oesophagus; but the Oesophagus is invested with a cellular Membrane, which communicates with the Pleura and Diaphragm in the whole Body. Hence the Air which was swallowed, passed out of the lacerated Gula into the cellular Membrane, which being inflated, produced an emphysematous Tumor throughout the whole Body. There was a certain Plaisterer fo dropfical, that he seemed to be buried as it were in a Case of his own Skin, so as to be almost concealed, his Legs equalling the Thighs of a healthy Man. Being very cold in a fevere Winter, he brought his Body too near a great Fire, and applied his swelled Legs to the burning Coals without any Sense of their being burned; and thus the Skin being perforated, the whole

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whole Quantity of Water, which was accumulated from Head to Foot throughout the whole Body in the cellular Membrane, was evacuated thro' Thus by a fortunate ill Accident, the Wound. the Patient was cured of his Disorder, so that in three Days time the Skin hung like a loofe Cloth about his Body. Here therefore the Communication evidently appeared betwixt the Cells of this Membrane in all Parts of the Body, in which the Water was collected. The ancient Egyptians being acquainted with Events of this Nature, did not perplex dropfical Patients with internal Medicines; but they passed a Needle and Thread thro' the Skin, leaving the Thread in the Wound to prevent it from healing, and thus the Water continually flowed out Day and Night. Butchers intend to free the Skin from the Flesh of Sheep or other Animals without wounding either. they usually make a small Incision in the Skin, and blow Wind underneath the Skin into the cellular Membrane; after which they drive the Flatus from the Head to the Foot betwixt the Skin and Muscles, which are by this means more neatly freed from each other; which is a manifest Sign how ample and ready a Paffage there is through the Cells of this Membrane communicating with each other.

§. 417. Immediately upon this Stratum of Fat (§. 416.) is spread a thick Intertexture of fubcutaneous Nerves 1 rendered very thick and tough 2 or strong by the hard Integuments of the Nerves; besides which, there are also numerous Arteries 3, Veins, and lymphatic Veffels, interwove together with the Nerves throughout the whole interior Surface of the

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Skin; from which Vessels the other smaller ones arise, which are seated on the extreme Surface of the Skin.

Throughout every Part of the Body where the cellular Membrane is expanded, either in a more or less conspicuous State, as it is more or less distended, there are many small Nerves distributed. which Vieussens confesses himself to have been never able to delineate, notwithstanding he formed Tables of an unufual Magnitude to express them with Truth. But it is evident from his Tables that no fewer Nerves are fent to the Skin than to the several other Parts of the Body. But Eufachius expressed them with Truth above two hundred Years ago, as is evident from his Tables which have been lately discovered. The subcutaneous Nerves are therefore collected together, after having passed through the cellular Membrane, and uniting with each other in great Numbers, they are at length erected upright in the Skin; whose Toughness or Callosity arises from the Dura Mater, which the Nerves throw off in order to form the Papillæ.

This Intertexture of hard Fibres is usually called the Skin itself, which being very tough is not easily penetrated by the Knife of the Anatomist, consisting almost entirely of Nerves, very strictly interwove and compacted together in an intricate Manner. But the Leather which we make use of is little more than the Nerves and small Vessels with the Integuments of the Nerves; for as to the soft and real Substance of the cutaneous Nerves, that is destroyed by the Artifice of Tanning.

The small Arteries of the Skin are extremely numerous; nor do they extend beyond the Skin: for Ruysch could never discover any Vessels in the reticular Body.

§. 418. But

§. 418. But the small Nerves of the Skin which arise 1 perpendicularly outwards from its fibrous Intertexture, form small Pyramids, which depositing their external Integument received from the Dura Mater, by that or the next Integument which they cast off, is formed the reticular Body of Malpighi, which he first discovered in the Feet, Hands, and Tongue; but these Papillæ are more accurately represented by Ruysch, who has demonstrated them throughout almost every Part of the Body; only the Papillæ are different in various Parts, and the reticular Body is perforated with as many Foramina as there are foft nervous Papillæ arifing up, which are transmitted, secured, and retained in order by the reticular Body. But these Papillæ appear the most numerous and conspicuous in those Parts where the Sense of Feeling is the most acute, as in the Tongue, Nipples of the Breafts, the Glans Penis, Vagina, and Labia of the Pudenda in Women, the Oesophagus, Stomach and small Intestines, in which Parts they are destitute of a thick Cuticle, and are but just covered with an exceeding fine Expansion continued to the external Cuticle; they also appear very conspicuous in the Ends of the Fingers and Toes, where they are indeed covered with a Cuticle, but somewhat thinner than in the other Parts of the Hand; but in all other Parts of the Body they are invested with a thicker Skin, appear smaller, less numerous, and are not so sensible. Lastly, the reticular

ticular Body itself appears to be entirely deftitute 2 both of fanguiferous and ferous Veffels: and the Papillæ themselves appear less and not fo tharp pointed after the Cuticle has been pulled off.

The fmall Nerves which are hard in the Skin through which they are distributed, join their Integuments together, and becoming foft, naked, and destitute of their Integuments which they throw off, they rife up perpendicularly outwards in all Parts of the Skin, and form short slender Tubercles, which are the pulpy and true meduliary Substance of the Nerves themselves in a pyramidal Figure, being usually called Papillæ from their accumulated Appearance like the Nipples of the Breafts, or like the Horns of Snails, constituting the immediate or true Organ of Touch, which Malpighi allowed only to be feated in the Tongue and Ends of the Fingers and Toes, but Ruysch has demonstrated, that the pyramidal Papillæ for the Sense of Feeling are found in great Numbers throughout every Part of the Skin, as well as in the Lips, Breasts, &c. and that in the Nose they perform the Sense of Smelling, that of Taste in the Tongue, and of Feeling or Touch in the twenty Ends of the Fingers and Toes. are so extremely fensible as to contract themselves upon the flightest Touch of any Body externally. When a Blifter is raised in the Skin either by Fire or Cantharides, at the Bottom of the Blifter a very fensible Jelly appears, which is the reticular Body intermixed with the nervous Papillæ. But those small Nerves which are changed into Papillæ, throw off their external Coat in fuch a Manner, that they lie at a small Distance from the Ends of the Papillæ, and form the reticular Body fo called called from its many Perforations through which the Papillæ are transmitted, and which Foramina are very conspicuous after the reticular Body has been taken off from the Papillæ. It is therefore not difficult to conceive, that there are as many Cases or Sheaths in the reticular Body, as there are Extremities of the Papillæ, in the same Manner as a Glove is furnished with as many Partitions as there are Fingers: and hence it is that in the small Fissures or Lines of the Skin, the reticular Body which receives the Papillæ is very thin in comparison with its Thickness in all other Parts. This Body is therefore immediately covered externally with the Cuticle, and it is only the external Surface of this which appears black in the Ethiopian, brown in the American, and white in the European: for the Cuticle itself in black People appears white, as we plainly fee when it has been raised by a Blister. Internally the reticular Body adheres to the cutaneous Nerves; and therefore the Cuticle is the first common Integument that invests the whole Body; next to which lies the Corpus Reticulare of Malpigbi, as the second Integument which we have here described; the third common Integument is the true Skin itself, and the fourth is the adipose Membrane. If you abrade this reticular Membrane, the short and soft Papillæ will appear naked and disposed in the Capsules of the reticular Body, to which the tactile Nerves and numerous Vessels are distributed; but under the Papillæ follows a tough hard Integument composed of the cutaneous Nerves, being the most material Part of the Skin itself, immediately after which follows the cellular Membrane before defcribed (§. 416.),

The reticular Body seems to have Vessels, though none can be demonstrated by any Art, because because they are much simaller either than the serous or sanguiserous Vessels; but that there are Vessels seems to follow from that kind of Leprosy which is called Elephantiasis.

\$. 419. From the faid nervous Intertexture arise perpendicularly small sharp pointed tough Threads in feveral Parts, which conjoining together from a bulbous Root form those Bodies which we call Hairs 1; but some of these Hairs arise immediately out of the Fat 2 itfelf, at a confiderable Depth, either from the Cells or small Glands which are interposed in that Membrane, and being propelled outward become gradually drier in the Air, often running for a confiderable Length thro' confining Capfules or Sheaths; and these Bodies or Hairs ferve to defend the Skin, fasten and secure the Pores 3, and to answer particular Purposes with regard to the Skin in various other Parts, as in the Cavities of the Nostrils or external Nose, 8c.

These Bodies or Hairs take different Denominations according to the particular Part where they are seated. In the Chin they are called the Beard, in the Eyelids Cilia, over the Eyes they are called Brows, in the back Part of the Head they are called Capilli, in the Nostrils Vibriscæ; and there are still others at the Pubes and in the Armpits, which with those appearing all over the Skin, are only distinguished by the common Appellation of Hairs, which yet are not to be found in those Parts which Nature has destined to a perpetual Attrition, as betwixt the Fingers, the Palms of the Hands, &c. Even in the young Infant, the Female as well as the

the Male at the time of Birth, the whole Skin appears beset with fine Hairs like the Down of a Peach, which viewed with a magnitying Glass appears like foft Wool. The People of barbarous Nations which inhabit towards the North are covered all over with Hair, and this was the Condition of Nabuchadnezzar, who being afflicted with Melancholy by divine Power, neglected his own Body. But the Hairs may be diftinguished into two or three Classes; the first of which may comprise all those which arise with bulbous Roots from the adipose Membrane, and the second the shorter Hairs which do not perforate the Skin but arise immediately from it, seeming to be a Production of the Extremities of the Nerves themselves. namely, a Continuation from the cutaneous Papillæ (§. 418.), each of which are composed of a very sensible Nerve passing through the reticular Body, after which they fend off a Filament which perforates the Cuticle, and from thence derives a kind of Sheath through which it passes to the open Air, where losing its soft and sensible Nature, it becomes quite destitute of Feeling; and that the Filaments which are continued from the Papillæ are thus conjoined together into Hairs, is demonstrated by the Experiments of Ruysch. If a Portion of the Skin which has been injected, is macerated for some time in Water, it will be no difficult Matter to separate the Cuticle, in which the Foramina will appear that transmitted the Hairs; but it is from the Cuticle that the Vaginæ or Sheaths are derived to the medullary Part of each Hair; and therefore when a Hair is pulled out it tears off Part of the Cuticle, and appears to have a round bulbous Root which was feated in the Skin The Hairs are therefore not a mere Continuation of the Cuticle, but they only perforate it, and

and derive an external Covering from thence, being themselves continued from the medullary Substance of the Nerve, from whence arises that Titillation produced by a gentle Extension of the Hairs. and which is so considerable in the Nostrils as to produce Sneezing; and even if but one fingle Hair is gradually pulled out of the Skin, either in the Beard, Eyelids, Nostrils, &c. it excites the most intense Pain; but if they are pulled out instantly, the Pain is then but for a Moment, ceafing almost as foon as it is felt. The Hairs are speedily renewed in the feveral Parts in which they at first grew, from the same Causes by which the Nails are produced. 2. Another Class of Hairs are those which are very long, and continued in a curling or twifted Course, as are those Hairs which are most exposed to the Air, which we see in People who fuffer their Beard and Hair of the Head to grow to their full Length, but of which we deprive ourselves by shaving close to the Skin. 3. We may again diftinguish a third Class of Hairs seated in those Parts of the Body which are in the greatest Danger of violent Attrition, as in the Scrotum, Pubes, Arm-pits, &c. which Hairs infert their Roots obliquely for the Length of two or three Lines within the Fat into a fort of subcutaneous Glandules, lest if they had been rooted not so deep but in the Skin itself, they might by the Contraction and Motion of the Skin, have been so agitated as to produce Pain, as for Instance, in the Scrotum, &c. These Hairs also excite a Titillation and Itching, by which they advertise the Animal of Insects harbouring among them; and they also exclude Insects from entering the Nose, Ears, Eyes, &c. in which Parts they foon grow again after they have been destroyed. When the Hairs in the auditory Passage have

have grown fo long as to touch the ceraminous Matter which lines that Cavity, it excites a wonderful kind of Titillation or Itching, whereupon the Person immediately endeavours to cleanse the Ear. For the same Reason Swine who have the Organ of Hearing seated very deep, love to rub their Ears against any Obstacle; and if it was not for this Sensation of Itching excited by the Hairs, the auditory Passage might grow together or be

stopped up.

At certain Intervals in the Skin are feated Oil-Ducts, from whence the Head becomes all over greafy if it has been covered up for some Days; which Oil not only lubricates the Skin but also the Hairs, both which are likewise moistened by the Humidity of the perspiring Vessels. But how neceffary this Liniment is to preserve the Hairs, we are taught by the Disorder called Trichiasis, in which the Hairs becoming too dry, split into many small Threads. The Eastern People are very industrious in anointing the Hair of their Heads, which was a Ceremony formerly observed in the making of Priefts and Kings. Perhaps this Cufrom might have been derived from the bad Confequences which they observe to follow from too great a Dryness of the Hairs. But besides this there is a kind of Exhalation in the Head different from that of all other Parts; for we there observe those Tumors which are called Talpæ, whenever the oily Cells have their excretory Ducts obstructed, so as to be themselves distended by the perpetual Accumulation of their contained Humour from the Arteries, infomuch that they have been fometimes observed large enough to hold three Ounces. Some improperly call this Disorder a scald Head, whereas it is a true kind of Atheroma, From hence we may understand

the Reason why cutting and shaving off the Hair of the Head produces a Change throughout the whole Body, and why removing the Hair in this Manner from the Head, often cures or at least eases intolerable Pains of this Part, which yield to no other Remedies; as is confirmed by daily Experience in France, Italy, Spain, and Britain, and

as we are affured also by Sydenbam.

The Skin viewed with a magnifying Lens appears full of Furrows in the Hands and Feet, not only disposed in those large Ridges which we perceive with the naked Eye, but also in lesser ones which traverse the former. Betwixt the Furrows there is an intermediate Space filled with a Ridge or a Bank. But the smallest Particles which the Eye can distinguish by the Glass are a fort of Scales, by the Connection of which together, the Cuticle itself feems to be formed, through which open an infinite Number of exhaling Veffels. The Hairs passing through the Cuticle are a fort of Stakes or Pins, to confine the Pores in their proper Order, that they might not be displaced and difturb each other; and this may be one of the principal Uses of the Hairs, which also serve to keep the Skin warm, defend the Cuticle from Attrition, to ferve as a Skreen to keep off Dust and Infects from the Eyes, Ears, Nofe, &c.

§. 420. But from the innumerable small Branches of the subcutaneous Arteries which are interwoven together, arise very subtle Vessels opening outwards, and which in a State of Health continually exhale 1 a thin volatile, odorous, saline and invisible Vapour from under the Cuticle 2; but when these minute Ducts are relaxed, or the Humours too forcibly impelled, the invisible Vapour is then discharged in the sensible Form of Sweat.

This Vapour may be demonstrated to the Eye by Experiments. If the Arm of a healthy Man that has been washed clean, is inferted into a clean Glass with a long Neck, you will be surprised to fee the Quantity of Liquor, which in a quarter of an Hour's time will be condensed on the Sides of the Glass, which will trickle down the Sides to the Bottom in the Form of a limpid Water having a little faline Tafte, and fomething of a fœtid Smell. The Cuticle is therefore furnished with exhaling Arteries, paffing through its Substance so as to communicate with the external Air, as is evident not only from the transuding of Water through these Vessels like Dew when injected; nor is this repugnant to the Affertion of Ruysch, when he fays, that neither the Corpus Reticulare nor Cuticle are furnished with any Vessels; for he means, that they have no Vessels capable of receiving any coloured Injection. The Moisture which this way exhales, is the perspirable Matter of Sanctorius. I have entertained fome Thoughts that the perspirable Vesfels of Sanctorius, might be the extreme Openings of the subcutaneous Nerves, since they are much less than the Vessels which discharge the Sweat. But even if the Diameter of a smaller Vessel be dilated, it may transmit a groffer Humour in a larger Quantity, which we call Sweat; and even fome imes Humours still groffer than that of Sweat, have been observed to pass through these Vessels. There was a Woman at Amsterdam, mentioned by Ruysch, whose Menses being suppressed at the usual Passages, were discharged by Sweating through the whole Skin of the Body. But the Skin has yet another Office by its Nerves being disposed in the Form

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Form of fensible Papillæ, to guard and give notice by the Sense of Touch of any Danger that might be threaten'd to the Body, while the other Senses are not affected, as in Sleep. It is a Piece of great Providence in the Creator, that he has given Pain to Man as a perpetual and infallible Judge whether any Object is either amicable or offensive to the Body, which is by this Sense revealed to the Mind. But that these Papillæ may be kept sensible and apt to make a true Report, it is necessary for them to be perpetually moistened with an oily and aqueous Humour that they may not become callous, nor degenerate into Hair or Nails; for a Papilla when dry is infenfible. The Tongue itself when it is become dry with a Fever, or by fleeping with the Mouth open of a Morning, is not capable of distinguishing Tastes. This is therefore one principal Use of the perspiring Moisture, namely, to keep the pulpy Extremities of the Nerves moift and foft; for when the Skin is deprived of this Moisture, the Sense of Touch is also depraved or abolished. Besides this the Skin is rendered soft and flexible by these Vapours. Mathematicians demonstrate that when a strait Cylinder is inflected, the Extremities are much extended; and therefore the Skin which cloaths the Articulations ought to be more flexible than the rest, as we see it is, not only by the perspirable Moisture but also by the oily or sebaceous Matter, which is most plentifully supplied to those Parts.

If these small perspiring Vessels are dissolved by a Blister or any caustic Medicine, their Humour is then collected under the Cuticle in the Form of a sharp Water or Ichor, raising the Cuticle into

a little Blifter.

§. 421. There are also besides these Arteries, the subcutaneous Veins 1, being distributed as before (§. 402.), i. e. small Vessels opening externally and terminating in the Veins, whose Office being not to exhale any thing, is therefore to receive or absorb 2 any Liquor or Moiflure which infinuates from without, and to convey the same together, first into the very thinnest Lymph, and from thence by degrees to the thicker Lymph, paffing afterwards to the Serum, and at length into the Blood 3 itself, with which it mixes; and the Truth of this we are convinced of from many and certain Experiments.

The Arteries are always accompanied with Veins throughout every Part of the Body: and even a happy Injection of the Skin itself demonstrates small Veins which are not furnished with Valves. .

<sup>2</sup> This Inspiration of Moisture is demonstrated by many Experiments. Even Hippocrates has pronounced the whole human Body in Health, to be perspirable as well inwards as outwards. Even Paracelsus writes, that as the whole Body sweats from the internal Parts outwards, so, on the other hand, there is a ready Passage from without inwards through the whole Surface of the Skin. hence we may conclude, that Paracelsus was not altogether fo unworthy of the Character of a Phyfician and a Professor, as is commonly faid and thought, unless you make a Skill in the Purity of Latin an effential Qualification in a Physician. He likewise adds an Experiment, for says he, I have nourished Men for several Days together by apply-U 2

ing nutritious Liquors to the naked Surface of the Body, (See §. 87. No. 12.). The Moderns have furnished us with other Experiments. It is well known that Cantharides being externally applied to the Skin excites a Fever. Bellini took off a Portion of the Skin of the dead Body of a Man who died in Health, and sewed it into a Bag in such a Manner, that the external Surface of the Skin made the Infide of the Bagg, and filling it with warm Water, he hung it up in the Air, and obferved that the Water sweated through it. Mr. Boyle has furnished us with several other Experiments in his Treatifes concerning the wonderful Subtlety of Effluvia, and concerning the Porofity of animal Bodies. There is therefore a free Passage through the Skin, Cuticle, and reticular Body of Malpigbi, by which watery Liquors may exhale, and be also again absorbed by their respective Veins, in order to return through the large fubcutaneous Veins into the Blood.

For the Blood would certainly be dried up by the continual Exhalation of Moisture, which is made every Hour of Life, unless there was to be some return made of the Moisture by these

absorbing Veins.

§. 422. But besides these exhaling and inhaling Vessels, there are larger 1 Openings or Ducts throughout the external Surface of the Skin, which discharge or exhale an unctuous 2 and oily 3 Substance, to relax, soften, and moisten the Skin, as well as to preserve its Warmth, and to prevent too great a Dissipation. There are still a good many other deep cylindrical and perpendicular Ducts, much larger than the former, on the Insides of which

which open abundance of exhaling Orifices, whose Humour being dried up, forms a Paste which turns black towards the Air, and may be pressed out of the Skin in the Form of a little Maggot or Worm 4; and this proves the Cause of many cutaneous Disorders.

These Cells are sometimes so much enlarged in a healthy Person, that they resemble Mustard Seeds. Ruysch was for many Years not well acquainted with the Nature of these Pores, as he writes in an Epistle to me, in which he imagines them to be mere excretory Ducts continued from the adipose Cells. But they are in reality lenticular Cells, in which an Oil is deposited from many small Ducts, where being retained and thickened, it is upon a proper Occasion discharged by cylindrical Ducts, which persorate the reticular Body and Cuticle. It is in these Follicles that the Leprosy, Itch, and other cutaneous Disorders are chiefly seated.

<sup>2</sup> All the Functions of the Skin depend upon its being foft and pliable, without which it becomes infentible, splits in the Hands, Lips, and other Parts, especially when the intense Cold of the Winter has contracted the oily or sebaceous Ducts in such a Manner that they cannot discharge their Contents. The Skin therefore stands in need of being continually supplied with an Oil, and for that Reason it is perforated at small Intervals with Oil-Ducts or Cells, that by the continual Warmth and Motion of the Parts, the Oil which is melted down may anoint and mollify the adjacent Skin.

If you press the Hand hard against a Lookingglass, there will be little Spots, even though the Hand was washed clean: and if the Face is rubbed

with black Velvet it will appear white with the Oil that is taken off from the Skin. When I paid a Visit to Lewenboec, he took a very clean Piece of Glass, and preffing it close to the Skin, it appeared to be rendered foul, and upon examining the Matter with a Microscope, it was found to be Drops of pure Oil adhering to the Glass. afterwards undertook a more accurate Experiment of this Nature, for after washing my Face clean with Soap, upon preffing the Cheek or Nose before a Looking-glass, a white, thick, and oily Matter was forced out in the Form of a little Worm, which weighed near one Grain, being of the fame Diameter with the federning Follicle; but upon continuing the Pressure longer, a true Oil came out. Such Follicles or Cells are feated in all Parts of the Skin, but they abound particularly in the Face, because that is much exposed to the Injuries of the Air and Weather; they are likewife feated among the Hairs, as in the Chin, Pubes, Scrotum, Arm-pits, and Anus; but the contained Matter frequently appears black from being corrupted or too long confined.

4 There are many Men who have their Skin foul and discoloured, or of a blewish cast, from this Matter being accumulated and condensed. But although this Matter is discharged in the Form of a Maggot by Pressure, yet it is not really so, as many have mistakenly imagined, though it must not be denied that sometimes real Insects are bred in the Follicles of this Matter under the Skin, as is frequently observed in Asia; and the Sirons, as they are called, dwell in these Cells when they cause the Itch, and Lice make their Nests there, in the Pthiriasis of which Distemper great Princes

have been known to perish.

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§. 423. Over all these is extended the Cuticle 1 or scarfy Skin, which by Reason of the Minuteness of its Vessels and connecting Fibres, may be eafily broke by the least Force so as to be entirely separated from the subjacent Parts. It is divisible into several Lamellæ or Scales, containing no Vessels which can be rendered visible by any Artifice; nor is it at all fenfible, but is composed altogether of small Scales 2 which are again divisible into smaller, 'till they come to an incredible Minuteness, and being cut or marked out into Furrows 3 and Ridges, it appears to be disposed in spiral Rows, which are most conspicuous in the Ends of the Fingers 4; and in the middle of the Furrows betwixt these Ridges, the sudoriferous Vessels are Pores, have a safe Outlet, on each Side of which and placed Rows of nervous Papillæ parallel to the former. From whence it is evident that the sudoriferous and exhaling Veffels, with the Papillæ for the Sense of Feeling, are defended 5 with this thin Covering without impeding or augmenting 6 the Senfe of Touch.

The Structure of the Cuticle is indeed wonderful in many Respects. When a Portion of the Skin taken from a dead Body, has been macerated a long time in warm Water, it almost entirely dissolves, and leaves only the Cuticle with the Hairs and Nails remaining; even in Putrefactions of the Skin, Inflammations or Gangrenes, the Cuticle is only elevated from the Skin without at all being corrupted. And in these Disorders like-

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wife the Nails are very eafily separated from the Parts to which they adhere. But the Cuticle is perforated with an infinite Number of Pores, infomuch that Lewenboec computes that 125000 of them open within the Compass of a Grain of Sand: but if this Computation is by much too large, yet we are certain that the Number of these Pores is very great. These Ducts or Pores feem to be of the arterial kind, fince they continually exhale the perspirable Matter; but there are as many inhaling Veins (§. 421.) interspersed through the Skin as there are exhaling Arteries, discharging the perspirable Matter of Sanctorius. Besides this, the Cuticle is perforated with many larger Ducts which discharge the Sweat, together with the Orifices of the Cells containing the febaceous or oily Matter, which by Pressure is discharged in the Form of a Vermicle (§. 422.), all which are conspicuous by the Microscope. The Cuticle also gives an external Case or Covering to the Hairs, and defends the nervous Papillæ; it is not therefore one continued or folid Membrane, but is perforated with many small Holes like a Net or Strainer. In the Blackmoor the Cuticle is found to be very white, the Blackness arising from the reticular Body which is placed underneath.

It is not the fæcal Part of any of the Humours which are discharged through the Skin, nor is it the glutinous Part of the Humours dried up over the Skin; but it is composed of an infinite Number of exhaling and inhaling Vessels, connected to each other by Scales, which are by degrees hardened and compacted together by the Air and the Contact of external Bodies, becoming callous by Attrition, in such a Manner that the intermediate Spaces or Rings are much harder

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than the rest of the Cuticle. From hence we may understand the Reason why the Cuticle is so easily separable from the Skin: namely, 1. Every Vascule is as small again at its Extremity in the Cuticle, and its Cohesion is there not half so strong, whence it may be separated or broke with half the Force. 2. As all the Extremities of these Vessels cohere together, they must ne-

ceffarily separate all together.

3 These arise partly from the Motion of the fubjacent Muscles, and partly from the Disposition of the nervous Papillæ. Under the Nails they are disposed longitudinally, according to the Length of the Finger, in most Parts of the Body they are rhomboidal, but in the Ends of the Fingers they are disposed in a spiral Order. It is the regular Order of these Papillæ, for the fake of which the Cuticle is thus disposed in the Ends of the Fingers. This was truly observed by Malpighi, namely, that the fensible Papillæ lie concealed in the Sulci formed by the Cuticle; but if the Sides of the Sulci open the exhaling Vessels which discharge the Matter of Sweat, as may be easily seen by the naked Eye in a clean foft Hand, it is apt to fweat in the Summer Time; and they appear still more conspicuous in the Palms of the Hand and Soles of the Feet. To these Sulci of the Cuticle the reticular Body very firmly adheres; and hence it is that when the Cuticle is abraded, the Corpus Reticulare comes off along with it; and from hence also we may understand the Reason of the intense Pain, which follows when a Gangrene invades these Parts.

† The Cuticle adheres to and is continuous with the Nails; for the nervous Papillæ which are feated at the Ends of the Fingers, becoming

hard

hard or callous, compose the long Filaments of the Nail, which we see by a Microscope continued in right Lines close to each other: but the Cuticle infinuates itself partly underneath, and at the Ends of the Fingers it is reflected back under the Nail, after forming the wonderful Sulci beforementioned; so that the Cuticle is extended both under and over the Substance of the Nail. But immediately under the Nail itself, the nervous Papillæ are naked, without being defended by any Cuticle of their own.

This is one of the principal Uses of the Cuti-The cutaneous Nerves are very foft, and like a Pulp; but by their Contact with the external Objects, they eafily deposit their Sensibility. and become hard or callous, as very frequently happens in the Palms of the Hands and Soles of the Feet of those People who are addicted to Agriculture, or to any other kind of laborious Exercife. Besides this, we even observe that the nervous Papillæ have a natural Inclination to degenerate from their own Nature, into that callous and infensible Substance which forms the Hair and Nails; betwixt which there is little or no Difference, except that in the Nails the Filaments which would have formed Hairs are cemented close to each other. Du Verney has demonstrated, that the cutaneous Papillæ of an Elephant are continued from its Snout, almost like Snails Horns, in which the Eyes of that Reptile are fixed. We likewise observe the same Productions of the Papillæ in the Snout of a Hog, and in the human Tongue; and if we apply a Bit of Sugar to the Surface of the Tongue before a Looking-glass, we shall observe that the Papillæ extend or raise themfelves up towards the faid Body. Therefore the Cuticle defends the Papillæ from being dried or injured

injured by the Air, or any other external Bodies, by covering them as with fo many Caps. But be-fides this, the Cuticle has many other inferior Uses.

We observe that the Cuticle renews itself after it has been abraded: and this it always does, provided the reticular Body of Malpighi is not destroyed; as, for Instance, when the Cuticle is raised and taken off by bliftering with Cantharides. But if the reticular Body of Malpighi is deftroyed, in that Case a Cicatrix or imperspirable Crust is formed, instead of the Cuticle. Finally, the Cuticle invests the whole external Skin; but yet it does not terminate where the ancient Anatomists have fixed the Termination of the Skin, as in the Lips, Eyebrows, &c. for the Cuticle is still continued with little or no Variation of its Texture, and passes under the Denomination of Epithelium, so called by Ruysch; and thus the Cuticle lines all the internal Cavities of the Mouth, Ears, Oefophagus, Stomach and Intestines; whence the Surface of this Integument appears to be much larger than is commonly supposed.

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## Of the SWEAT.

S. 424. THE Sweat is discharged out of open Orifices arising from under the Scarf-Skin, and passing through Perforations in the reticular Body by excretory Vessels, which are sent out from a sort of glandular Bodies, commonly called Glandulæ Miliares, which lie upon the Fat, and are dispersed

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persed throughout the whole Body, being surnished each with an Artery, Vein, and Nerve, as well as with an excretory Duct, which, as we said before, perforates the reticular Body (§. 418.), and discharges the Sweat by an open Orifice in the Cuticle (§. 423), which Orifice seems to be covered with a hollow Valve 2 capable of being elevated, and placed in such a manner under the Scales of the Cuticle, that it can either transmit or confine the Humours. And this is the principal Organ of the gross Sweat; to which add the other smaller Vessels of Ruysch 3, which do not so nearly approach the Fabric of a Gland, but usually discharge a more thin 4 or watery Sweat (§. 420).

Ruysch does not admit of any miliary Glands, but it is no difficult Matter to demonstrate them: for if the Arm of a healthy Person be exposed to the cold Air, the Skin immediately rifes up into an infinite Number of small Tubercles, insomuch that the whole Arm appears rough like the Skin of a Goofe, all which Tubercles again disappear fo foon as the Warmth of the Arm is restored either by Friction or by returning the Clothes; they even vanish of themselves after a while, if the Arm is continued longer in the Cold. But what can be more natural and plain than for us to conclude from hence, that the Cells or Follicles in the Skin, are full of Matter to be discharged through the Cuticle, and that when the Humour continues to be secerned while it cannot be discharged, by reason of a Constriction in the Pores by Cold, it therefore distends the Follicles by its Retention. But the same Tubercles disappear after the Cold has continued some time, so as to penetrate into the Skin itself, and contract the Follicles by evacuating their Contents; and they also disappear by Warmth or Friction, when the Pores are opened fo as to evacuate their Contents: it is therefore manifest that they must be a fort of Machines capable of expanding and contracting, and that they contain a particular Humour of their own. But it is no matter whether we call them miliary Glands with Malpigbi, or simple Follicles or Drains according to Ruysch. I have even obferved the Nature of these Follicles in several Parts of the Body, so as to obtain a better Idea of them than Ruysch himself who prepared the Parts: I diftinguished small Arteries and Veins which were fpent upon the Membrane of each Crypta or Cell, the Cavity of which terminated in a much narrower Duct; the Necessity of which Mechanism is demonstrable from the Nature of the Secretion itself. Ruylch makes these Emissaries to be the Extremities of the fudoriferous Veffels themselves; whereas there is not the least room to doubt but that they are real Cryptæ, which not only contain a thin Humour, but also retain the same for some time, so as to render it thicker before it is discharged. There are many of these in the Face, Lips, and Corners of the Mouth, as also in every Part of the Body, which has any Motion or Attrition over another; but this unctuous Humour which is required for preventing the Attrition of all Parts of the Skin, must be supplied from small Glands.

The open Orifices of all the cutaneous Follicles, and the Mouths of the exhaling Arteries, are each of them furnished with a fort of Valve or Stopper, the Nature of which was first discovered from an Examination of them in brute Animals. Du Verney observed that in the Cuticle of an Ele-

phant,

phant, each exhaling Vessel was furnished with a Cap or Cone, like those of Sugar-bakers, which was moveable so as to give the exhaling Humours a free Passage into the Air. It is indeed true that in the human Body we find no fuch Machines as thefe, but there are Scales which fold over the Mouths of the exhaling Veffels, and perform the fame Office, that is to fay, the exhaling Arteries open obliquely under the Scales of the Cuticle. After the Feet have been well washed and cleansed. if you wear a Pair of black Stockings, you will fee continually that a white Matter adheres to them from the Skin, which being viewed by the Microscope appears to consist of mere Scales. These Scales being eafily rubbed off, are as speedily renewed again; but their Office is to cover the Mouths of the cutaneous Pores, so as to moderate the Discharge of their Humours, and prevent any groß Matter from entering from the Air without, so as to obstruct the Humours, and render them impervious.

is If the Cuticle be removed, and a ceraceous Injection thrown into the Arteries, it will transude through the Membranes of the Nose, and be discharged almost like the Mucus which covers that Membrane. Even after mature Consideration, I must consess that much the greater Part of that Humour which we call Sweat is discharged by Vessels continued directly from the Arteries, and that the Quantity of Sweat which comes from

the Follicles is much less.

<sup>4</sup> The Sweat is a watery Liquor, but much thicker than Water itself, coming from the exhaling Arteries of Ruysch in the Skin, and discharged by Emissaries belonging to the Plexus of subcutaneous Vessels. When a Person is hot either by voluntary Exercise or by a Fever, he discharges

discharges a yellow Sweat which stains the Clothes with Spots; and this follows, because the Force urging the Humours outwards is fo great as to propel groffer Parts of the Fluids than are naturally used to pass that way; and at the same time the Cells receiving the Sweat and Oil are washed out and discharged of their thicker Contents, at the fame time also the exhaling Vessels are so dilated as sometimes in great Agonies and violent Heats to discharge even the Blood itself. which rushes forth by these Passages; a notable Instance of which we have in our Saviour. faw a Woman at Amsterdam who discharged her menstruous Blood through the Pores of the Skin in the Head; and the same Spectacle was viewed by many curious and learned Persons: and we have an Account of an Irish Nobleman in the Philosophical Transactions, (No. 171.), who had a periodical Discharge of red Blood from the Extremity of his little Finger.

§. 425. The Sweat thus separated and discharged is various in its Nature, according to the Variety of Weather 1, the Soil or Country 2, the Sex, Age, and Habit of the Patient, and the Parts 3 or Emunctories themselves, with the Diet 4, Course of Life, and the time of its Concoction 5, almost in the same manner as we observed of the Urine (§. 368, & seq.)

But Sweat is hardly ever found in a healthy Body, unless some Excess or Error 6 has been committed in the fix Non-naturals. The first immediate Effect of Sweat is always prejudicial, but by Accident it is sometimes service-

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both in its Quantity and Quality: for the Nature of the Sweat in Europeans is very different from that of the American Inhabitants.

In general the Sweat of Men is more aerid and

fmells stronger than that of the female Sex.

Plastic, that it may distil along the Hairs, and equally anoint them that they may not split by being too dry. The Nature of the Sweat which exhales from the Armpits is very different from that which is discharged from the Feet; and this Difference is very perceptible both in the Smell and Taste. In the Feet the Sweat turns to thick Fœces, while in the rest of the Body it forms a kind of Liniment like Soap. That the cutaneous Discharge is very different in its Nature, we are taught by the Crises of Diseases. If a Bubo arises in the Pestilence, either under the Arms, Ears, or in the Groins, it is usually salutary, whereas it is of no Service in any other Part of the Body.

There have been some Men known to discharge an acid Sweat, while others exhale a putrid and setid Vapour. The Laplanders who live upon Fish, have their whole Skin smelling like a setid Pickle or Brine of Fish, much like the Oil of Whales, which is called Blubber. Those who eat Onions and Garlick carry the Scent of their Food in their Sweat. And in general the more the Body is exercised, the more acrid are the Salts, and the more subtle the Oils which compose the Sweat, and the Scent and Smell is also proportionably

more fætid.

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The Sweat differs in every Degree of the Concoction of the Aliments. There is a Sweat from the Drink, a Sweat from the Chyle, and another kind of Sweat from the Serum of the Blood; and even urinous Sweats happen in those who are afflicted with an Ischuria (§. 384). For there is a near Resemblance betwixt the Matter of the Sweat and Urine; and the Sweat being increased, the Discharge of Urine is diminished, and the Reverse; for if there is a great Discharge by Urine,

no Sweat can be expressed.

6 A Person in Health will not sweat, unless he is too much heated by Exercise, or by too plentiful a Use of Spices, &c. if moreover there is no thin Liquor drank at that time, the Sweat will then be more yellow, foetid, and thick. But the Reason why a healthy Person does not sweat, consists in the Smalness of the sudoriferous Vessels, which do not transmit such gross Particles, unless they are urged or dilated by the Impulse or increased Motion of the Humours behind, or unless the Blood itself is more diffolved than usual, as it happens in fome Diseases; or lastly, unless the sudoriferous Veffels themselves are too much relaxed, as remarkably happens in fainting Fits. It is an Obfervation of the Ancients, that the Body falls away by too profuse Sweats. In exercising the Body, it ought to be taken for a Rule to leave off as foon as ever a Sweat appears.

For it always denotes, that there is fome preternatural Condition of the Blood in the Body.

Seat of a Disease is in that Part which sweats. Yet a Sweat may be of Service by Accident, because it demonstrates that the Skin, which was before obstructed, is now open and pervious; and also that a considerable Portion of the noxious Humours

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are discharged in the Sweat. Many acute Disgases go off in critical Sweats. For fo long as the inflammatory Disposition of the Blood continues, fo long will the Skin be dry, and no Sweat can be feparated, because of the Thickness of the Humours: but when a Sweat appears, it demonstrates that the Vessels are relaxed, and that the morbifick Matter is attenuated, whence we may reasonably hope that the Disease will be happily terminated in Health. But such a critical Sweat is usually very thick and fætid. Sydenbam has made it an Observation in the Plague, that those Patients recovered, who towards the End of the Disease continually discharged a viscid Sweat for twentyfour Hours successively: and thus also a Sweat following the Bite of venomous Animals is good, inafmuch as it evacuates the Particles which were conveyed into the Blood.

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## Of the Sanctorian Perspiration.

S. 426. BESIDES the afore-mentioned fudoriferous Vessels, there are other exhaling Vessels still smaller, which open obliquely under the small Scales 1 of the Cuticle, and which are of that Subtlety, that Lewenboec computes that 125000 2 of them open in the Space of a single Grain of Sand, and through these is perpetually transpired a very subtle Humour from every Point 3 of the Body, called from its Inventor the Sanctorian Perspiration, who not only first discovered, but

but has also the Glory of compleating this material Doctrine of the perspirable Matter.

But these small Scales are the Extremities of the excretory Ducts inslected over the Mouths of the

exhaling Veffels.

<sup>2</sup> When Lewenboec by his Glasses, which surprisingly magnified the smallest Bodies, could not clearly discern these small perspiring Vessels, he concluded by deducing an Estimate from thence, that 125000 of these Vessels opened within the

Compass of a single Grain of Sand.

If the Hand be inferted into a Heap of Ice, which has been preferved under Ground in the Summer time, it will fmoke or fume in a manner as if it was on Fire. But fuch a Fume or Vapour is continually exhaled out of the Body; nor is it produced by Cold, only being before invisible, it is by the Cold fo much condensed as to be conspicuous to the naked Eye: thus the Breath in Summer time is not perceptible as it passes out of the Lungs, but by the Winter's Cold it is so much condensed as to appear like Smoke. If an intense Cold could be fuddenly produced in a close Chamber full of Company, one Person would not be capable of feeing another through the Fog or Vapours which exhale from their own Bodies, almost in the same manner as the Poets feign the Gods to be hid each in their proper Cloud. In India the Heat is perpetual, nor can a Person's Breath or perspirable Vapours be there at any time feen; infomuch that when the Indians are brought into the colder Climates of the frigid Zone, they are surprised to see a kind of Smoke evacuated by their Mouths, as if a Fire was contained within them. If a Piece of gold Coin that has been well polifhed and cleaned, is made very cold, as it may even in Summer, by dipping

dipping in an artificial Mixture of Sal Ammoniacum and Water, upon applying it afterwards to any Part of the Body, it will be obscured by the perspiring Vapours. If the Arm is inserted into a glass Receiver, the exhaling Vapours will be condenfed into Drops hanging upon the Sides of the Glass; it is therefore certain, that a moist Vapour continually exhales from the Surface of the Body. And these Vapours flying off in an invisible State, are called the perspirable Matter of Sanctorius; but when the small Particles of these Vapours are discharged fo near each other, as to come into Contact, and form little Drops, we then give them the Denomination of Sweat. But as there are exhaling Vessels opening throughout every Point of the Cuticle; fo likewise, agreeable to the Course of Nature, there must consequently be small inhaling Vessels corresponding to the former. But both these Kinds of Vessels were very well known to Hippocrates, who includes both Kinds of Perspiration, exhaling and inhaling, in a very few Words, when he tells us, " That all the Parts of the Body "perspire from within outwards, and from without "inwards." But he has likewise observed, that there are Cavities in the Body, which in a healthy State are filled with Spirits, but in a difeafed State they are filled with Ichor. By Spirits he understands an infensible Body, which yet produces a considerable Effect; and by Ichor he intends the same insensible Spirits condensed into a visible Humour. After Hippocrates, Galen has left us several material Pasfages concerning the Perspiration. But the first who made any Estimate of this considerable Discharge was Sanctorius, an Author entirely addicted to Galen, and who with incredible Labour, and innumerable Observations made during the Space of thirty Years, compiled together the most material Part

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Part of the Doctrine into a small Book of a few Pages, reducing the particular Experiments into a few universal or general Rules, admitting of no Exceptions. I must in short confess, that these Aphorisms of Sanctorius, with those of Hippocrates, are Writings of greater Merit than any other in the whole Art of Physic; and even if we compare the Merits of these two together, the Preserence will perhaps be readily given to Sanctorius.

§. 427. This Exhalation arises from the whole external Cuticle, as also from the Cuticle of the Mouth, Nose, Fauces, Larynx, Lungs, Oesophagus, Stomach, Intestines, Bladder, and Uterus; so that the Quantity of it exceeds the aggregate Quantity of all the other Fæces together: for in Italy a Person who is strong or middle aged, lives regularly, and uses a moderate Diet, discharges as many Vapours from the external Skin, Mouth and Nostrils, as is equal to five Eighths of what was taken into the Body 3.

The whole Surface of the human Body, without excepting any Part, is perspirable, except a Cicatrix should be any where formed by a Confumption of the adipose Membrane, or a Callosity in any Part of the Cuticle. But the Scarf-Skin is extended or continued much beyond the Skin itself, which terminates at the Tarsus or cartilaginous Edge of the Eye-lid; whereas the Cuticle is inflected under the Eye-lid to the Bulb of the Eye itself. The Skin itself is hardly continued above the tenth of an Inch within the Nose, terminating suddenly as if it was cut off, while the Cuticle still continues all over the internal Surface of the Nose.

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We fee that the Skin terminates abruptly in the Lips, in a manner as if it was cut of; but the Cuticle itself enters the Mouth and covers the Cheeks and Gums; then again it becomes thicker upon the Tongue, almost as it appears in the Hands and Feet, and then it goes on to cover the Infide of the Trachea and Lungs, with the Oesophagus, Stomach, and Intestines. Perspiration is therefore made as well from the internal Surface of the Nose, Mouth, and especially the Lungs, which last Exhalation is by Sanctorius computed to be one fixth Part of the whole Perspiration; having perhaps made the Experiment by condenfing his Breath in a Glass. In extreme cold Weather by blowing my Breath against a Glass, it has been instantly covered with watery Drops, which in a fmall Space of Time have been converted into Ice; and by this means one may weigh the Moiflure of the Breath, provided we can have the Opportunity of Cold whenever we please. But wherever there is a Cavity in the Body, there is Perspiration carried on. Even a thin Liquor exhales into the feminal Veficles as well as into the urinary Bladder. If the Moisture be wiped off from the Pleura, it grows moist again, and if you wipe it dry a fecond time, the Humidity will even still return; but then this internal Perspiration is not evacuated from the Body, but absorbed through the Veins destined to that Office.

If you should be surprised that an invisible Vapour should carry off so large a Quantity in proportion to what is evacuated by the other Emunctories, you need only reflect and consider upon those Vapours which float in the Air and are collected together about the Tops of the Mountains, so as to produce the vast Quantities of Water, which appear to us in the Form of

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finall Rivers, or Springs and great Showers of Rain.

3 Sanctorius spent thirty Years in making Experiments, the infinite Number of which he reduced to a few Observations and general Rules. He found that the Weight of his Body, for Example, was at one Day 120 Pounds, and the next Day at the same Hour it was also 120 Pounds: but then the Urine and the intestinal Fæces weighed almost three Pounds, while the Aliments both folid and fluid taken into the Body, weighed eight Pounds; from whence he concluded, that as no Addition was made to the Weight of the Body, the other five Pounds of the ingested Aliments must have passed off by some unknown Courses infomuch that of eight Pounds of Meat and Drink only four Ounces was evacuated by Stool, fixteen by Urine, and twenty four at least exhaled by infensible Perspiration.

§. 428. The great Subtlety 1 of these Vapours, and the equable 2 or uninterrupted Manner in which they are continually and very copiously 3 discharged, with the Sense of Lightness 4 which they produce in the Body, the Weight of which is increased 5 by the Balance without any Sense of Heaviness after Sleep 6, demonstrates the Person to be in the most perfect Health, and is also one of the principal Means of preserving 7 Health.

The most healthy Person who commits no Error in his Diet, nor in any of the six Non-naturals, will not evacuate any sensible Sweat, but nevertheless he will be sive Pounds lighter in the Space of twenty-four Hours by the Exhalation of this invisible Vapour. But the Cold of the exter-

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nal Air cannot but constringe the cutaneous exhaling Pores, so as to reduce the Mouths of each to a smaller Diameter than they naturally had before; and this is evident from the common Experiment by which the same Pores being quite closed by extreme Cold, the retained Vapours elevate the Cuticle into small Tubercles. In the mean time what Hippocrates has pronounced is certainly true, namely, that in the Winter and Spring the Viscera are warmer, and digest more powerfully; fince at those times we eat more and sleep better. But these Observations demonstrate that in Winter and Spring, the ingested Aliments are more easily concocted and evacuated in very thin perspirable Vapours; but Health is always the more perfect as this perspirable Matter is more subtilized; and it may easily appear, that no small Force is required to be capable of attenuating Beef, for Instance, fo as to exhale or flie off in volatile Vapours. Therefore the smaller the Pores the more perfect is the Perspiration, since they only exhale the most subtle Particles: and Perspiration is always more plentiful in proportion as a larger Quantity of the Aliments are attenuated into perspirable Matter by a healthy Person.

For Perspiration is not easily disturbed by slight Causes, but continues regularly the same for a long time; the Effect of which is to conduce to long Life, provided the Weight of the Body always continues the same, whether the Person eats little or much: for the Person who daily finds his Body return to the same Weight for many Years, such a one is disposed to live long. Even this is a sure Sign of a strong and healthy Habit, since it supposes a constant Equality of all the Powers which together produce Health. Before any Disease the Perspiration is always disturbed, being either

either diminished, suppressed, or render'd sensible in the Form of Sweat, when it ought to have been invisible; and then we perceive a Heaviness in the Limbs. Wasting Bodies often become a whole Pound heavier within the Space of an Hour. If you restore the Perspiration to a gouty or dropsical Foot, you will have performed all that is necessary towards a Cure. Where-ever a Phlegmon is seated, no Perspiration is there carried on. In all acute Diseases, a Regard must be had to the Tongue and Eyes: for if the Tongue appears covered with Mucus, and the Eyes look red, it is a certain Sign that the Perspiration is diminished throughout the whole Body.

Perspiration, can be neither crude nor half concocted, but must have passed through the several necessary Degrees of Attenuation, so as to exhale in the Form of Vapours; and therefore in general the Person is better in Health, as the Perspiration

is larger.

\* The Body feems light as to Sense, whenever it perspires equally; and this happens when all the Humours of the Body are duly circulated through their respective Vessels. But that Part of the Body which perspires less than the rest, must be heavier; and if the whole Body does not perspire, the Heaviness will be continued throughout the whole. If the Perspiration is frequently interrupted, and as often restored, then the Weight of the Body continually varies. A healthy Man weighing two hundred Pounds, does not perceive any thing of that Weight when he stands upon his Feet; but if he is afflicted with some Disease, he immediately feels a Heaviness all over his Body, which he is scarce able to support. For the Body seems light and insensible of its own Weight only, when all the

the Humours are pervious, and move freely and equably through all the Series of decreasing Vessels, in such a manner that all the Humours which are thinner than the Blood itself may be successively derived from thence, and pass readily into and through their respective Vessels; and this demonstrates that the Solids are most exquisitely adapted to the Fluids, and the Fluids or Humours to their

respective solid Vessels.

If a Person grows three Pounds heavier within the Space of a Year, and yet does not perceive
any Impediment in the Exercise or Motion of the
Pants, it is a manifest Sign that the Powers of
Health are persect and well regulated in such a
manner that they cannot destroy each other: and
in general the Body appearing to be heavier by the
Balance, and yet not heavier as to Sense, is a sure
Sign of persect Health; for such a Person will
neither sweat nor discharge much either by Urine
or Stool.

If the Head appears free for exercising the Faculties of the Mind, it is a Sign that Sleep has had a good Effect by evacuating the redundant Humours in the Form of perspirable Matter; but if the Head feels dull and heavy, it is a Sign that the Vessels of the Brain are not duly pervious, and that the Perspiration itself is not rightly performed, whence Disease must be the Consequence.

If a Physician knows how to retain the Perfpiration in an equable and just Degree, he knows the great Secret of curing all chronical and acute Diseases. But since we are destitute of any such Method, we must endeavour to restore or augment the Perspiration in proportion to its Desici-

ency.

§. 429. But when this Discharge recedes from the afore-mentioned Conditions (§. 428), it is a most certain Sign, and almost the first Cause of Diseases 1 in the Body.

In those Persons who have a Fever, or a Pleurefy invading, I have experienced in myfelf that the Body is dull or heavy for two or three Days. before the Disease, being easily fatigued and out of Breath by the least Motion or Exercise. Hence Hippocrates observes, that a spontaneous Lassitude is a Sign or Forerunner of Diseases: but this Laffitude is also a Sign of a diminished Perspiration. If a Person perspires less than usual but for the Space of a Day, a Heaviness or Lassitude will be perceived. From hence we know when Perspiration is impeded; by reftoring which, we reftore Health. But if through fatiguing Bufiness, or any other Cause, you neglect this Evacuation, and inadvertently return to Labour, the whole Power of the Disorder will be then returned upon the Body; from whence it can be never freed, but by restoring the Perspiration. In short, the Cure of a Pleurify, if we rightly confider its Nature, confifts in restoring the Perviousness of the obstructed Vessels, and in rendering the gross Humours sufficiently fluid: both which Intentions are answered by procuring a free Perspiration. Hence those who have acute Fevers neither sweat nor perspire in the Beginning of the Disorder; but if a night Moisture breaks forth spontaneously through the Skin before the third Day of the Difease, the Patient is out of Danger, and the Perspiration restored. Nor can Obstructions of the smaller Veffels be removed, unless the larger Vessels are first rendered pervious. The Perspiration is therefore a

316 Of the Perspiration. § 430. fure Sign both of the approach and going off of a Disease.

§. 430. This insensible Evacuation is preferved 1, increased and restored by the Viscera, Vessels and Fibres being continued in full Strength; by exercifing 2 the Body, until a flight 3 Sweat begins to appear; by a moderate Use of Venery 4 occasioned or excited by the natural Strength of the healthy Body, and not by any Instigation or Advice of the Mind; by continuing the Skep for seven or eight 6 Hours, with the Body well covered 6 \*, but not oppreffed with too great a Weight of Bed-cloaths 7; by affecting 8 a moderate Degree of Chearfulness or Joy, by Youth, and the Use of light solid 9 Food, well fermented 10, and seasoned with light Spices, avoiding every thing fat or oily in all Shapes; and lastly, by a pure, calm, dry, heavy, and cold Air 11.

All those Parts of the Body which elaborate the crude Chyle, and make it pass through all the Degrees of Attenuation, so as to pass off at length in the State of invisible Vapours or perspirable Matter, are here intended: and therefore the Stomach, Intestines, Heart, Lungs, and all the Arteries, &c. are those Parts, upon the Strength and healthy Disposition of which depend the Formation of the Chyle, and ultimate Attenuation of it, in order to evacuate some Part of it by Perspiration. But since the perspirable Matter of Sanstorius is the ultimate and finest Excretion in the Body, such a Degree of Health and Strength is required in all the Parts, as may be sufficient to duly circulate

culate and attenuate the Juices. Hence Hippocrates observes, that the Viscera are naturally stronger and warmer in the Winter and Spring; though Helmont opposes this Doctrine, and contends that the Venters are at that time colder: but he did not understand the Mind of Hippocrates; for the divine old Man intends that Nature generates more Warmth internally in the Winter. For fince the external Air is at that time very cold, and continually takes off some Part of the Warmth of the human Body, and yet we see that so much Motion is produced by the vital Powers, as fuffices to render the Person capable of all the Actions of Life, and at the same time to produce a considerable Atmosphere round him much warmer than the Air; it is evident, that the Power of the arterial System must be at that time great, and capable of circulating the Humours through the Body with a fufficient Degree of Motion. Hence it does not feem extraordinary or incredible, that the internal Parts should be warmer in Winter than in Summer: for there is no Effect produced by the Viscera or Veffels upon our Humours, except that which they make by Pressure and Attrition; nor are the Viscera any thing more than various Heaps or Asfemblages of Vessels, by the Efficacy of which the groffer Humours are attenuated to a great Degree of Subtlety. And therefore a fimple Contraction of the solid Fibres and Vessels will be (cateris paribus) the Cause of the most persect Digestion of the Aliments. And therefore the Winter's Air with Frost, free from Wind and Clouds, being calm and heavy, conftringes the Fibres of the Body, and increases their Strength, by which a greater Part of their Humours are elaborated into thin perspirable Matter: and therefore in the sharpest Winter we are healthy, strong, very hungry, and perspire more largely. But the Ancients erred in thinking that a serene

Air was the lighteft.

Our Species would live for a very long Time if they were to be never diffolved by Motion, nor spoiled by Idleness: for the Body being too much exercised, renders all the small Vessels callous; and too much Rest causes Stagnations and Obstructions of the impervious Humours. The Medium therefore betwixt Idleness and violent Exercise ought to be encouraged, to render the Humours pervious through the Vessels and dispose the Body

to long Life.

3 The Perception of an unufual Heaviness in the Body, gives fome Reason to fear that Disease is at hand; and therefore let the Body be exercised till a Sweat begins to appear, but yet not to fuch a degree as actually to produce a Sweat, but only a flight Moisture of the Skin. Thus if the Diforder is removeable, it will be carried off by refloring the Perspiration, and the equable Action of the Solids and Fluids upon each other. Nor can Perspiration be restored before the Parts have thus recovered their healthy State. This Motion or Exercise of the Body before Meals, is likewise one of the best means to restore a languishing Appetite. But we perspire more in twenty-four Hours by a gentle Exercise, than if we use such a violent Motion of the Body as to produce a Sweat. For although a larger Evacuation is made in a fhorter time by Sweat, yet that will stop after a while, and the remaining Part of the Day will be attended with a less Perspiration from the fupervening Cold; whereas if you only exercise the Body to as to increase the infensible Perspiration, the Skin will remain in a kind of warm Atmosphere, and continue to perspire. Celsus

4 Cellus observes that this Exercise renders the Body light, only upon certain Conditions, when he fays, that Venery feldom used stirs up the Humours of the Body to a brifker Motion, but too frequently used dissolves and consumes them. Those who have laboured under a Gonorrhæa, who sweat profusely, or discharge too great a Quantity of Saliva or Urine, all fuch Persons perspire less than others. They who have taken a purgative Medicine find themselves oppressed with a fort of Heaviness, some time after the Operation of the Medicine, and this notwithstanding they discharged three Pounds of intestinal Fæces; for the Santtorian Perspiration is by that means diminished, which in a healthy Person is of itself more than equal to all the other Excretions. The fame is also true of the Sweat, after which the Body is found to be likewise heavier.

It is not a little furprising how much Sleep conduces to Perspiration. Sleep is necessary to Health, and therefore ought not to be neglected. as many have taught. Those who break their Sleep in order to make the Night-hours as the best Time for their Study, do not act agreeable to Nature; for by studying in the Night-time, Sleep creeps upon the Body, and the Intellects are not fo acute. We fleep more in the Winter time, and we are in that Part of the Year stronger. But no Sleep naturally follows unless the Body be moderately warm, for we do not reckon that Lethargy which is induced by the most severe Cold to be a true kind of Sleep, for it is in reality a Disease. When we sleep therefore the Body is suspended as it were in a vaporous Bath, namely, in the Atmosphere of its own perspirable Vapours confined by the Bed-cloaths. But how great a Power the retained Exhalations of the human

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the Application of Emplastures, under which the obstructed Parts are mollissed, not by the Virtue of the Plaister, but by the perspirable Matter itself, which is repelled and confined by the Plaister, so as to adhere to the Surface of the Skin in the Form of moist Drops. In Sleep therefore the cutaneous Vessels are mollissed, and render'd extremely pervious, since the Perspiration is at that time larger than at any other. But too much Sleep is prejudicial, as Sanctorius observes, since it renders the Body stupid, and apt to retain the Matter, which ought to be transpired in the Day time.

human Body have upon the Skin, is evident from

tremely dangerous, since it obstructs the Perspiration, and causes the worst Diseases; only the sleeping one Night in the open Air in the hot Countries, produces the most dreadful Diseases, compounded of a Palsy and Convulsions, termed Beriberi. Even in Europe, if young Men sleep with their Bodies uncovered, they become rheumatic when they grow old, and are troubled with the Gout irre-

moveably fixed.

Lower has supplied us in another manner with the true Time for sleeping. For if a healthy Perfon fasting takes a large Quantity of Milk, Water, and Bread boiled together, the Blood which is drawn from a Vein seven, eight, or nine Hours after, has a fort of Chyle like Cream swimming upon it (§. 131.) But if a Vein is opened ten or twelve Hours after, there will be yellow Serum instead of Chyle. Therefore the Perspiration does not succeed well, until all the crude Juices derived from the Aliments are first digested or attenuated by the vital Powers; and this cannot be expected before ten Hours are past after the Meal.

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of the Blood being pressed from the Surface of the Body, should flow in too great a Quantity upon the Brain, which is free from the same Pressure. And besides this, a Person who lies covered with too many Cloaths is obliged, by the Sense of the Oppression, to move and turn himself about in the Bed, which obstructs the Perspiration. But we learn from Experience, that the most violent Labour, or long satiguing Journey, does not tire a Person so much as often turning and tossing about

in the Bed during the Space of one Night.

8 Sanctorius has laid it down as a Rule founded on Experience, that extreme Joy increases the Perfpiration fo much, as to fuddenly exhaust the Body of its thinner Juices, and prevent the animal Spirits from following in a continued Course through the Nerves: and hence it is that more have been known to die with extreme Joy, than with Grief. We read of a Woman, named Lacana, who being perfuaded that her Son was killed by the Enemies Sword, when she suddenly saw him return not only alive, but adorned with the Marks of Victory, she expired in embracing him. I knew an Instance of a Girl, who went from Holland into Asia to see her Brother; but he expecting her, order'd a splendid Equipage of Plate to be got in Order, and commanded his Servants to furnish a magnificent House for their new Mistress his Sister; but she being surprised at his vast Riches, and overjoyed with his Kindness, expired in the Consternation. But moderate Passions of the Mind. accompanied with Joy, conduce much to Health.

Pigeons, &c. is foon digested, especially when dressed with Onions, Garlick, and other Spices. But Lard or Bacon, and all fat Substances, diminish Perspiration. Sanstorius has handled this Mat-

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ter very well in his Aphorisms, in which he has given us more Instruction than has been wrote concerning the Nature of the Aliments in the vaft Volumes of the Ancients. But Perspiration succeeds the best, when lean Meat is taken sparing. ly, and with folid Bread; and the drier the Flesh. or the harder the Bread, fuch as Bifket, the more easy is it to be digested, provided the Organs are strong enough. The Slaves which row the Gallies in the Mediterranean live very well in Health only upon Bisket Bread, Vinegar and Water, so as to undergo the hardest Labour continually, without being able to get any Sleep, but what they take in an erect Posture. Roasted Meats are more perspirable than those which are boiled; and Bifket-Bread is more easily attenuated in the Blood, than a Decoction of Barley. But fat Substances obstruct the smaller Vessels, and impede Perspiration; or even if they are externally applied, they excite an Inflammation. Flesh Broths easily pass off in Sweats.

Pread still lighter than Flesh. They who eat hot Roles or Cakes will perspire one Pound less in the Day than they otherwise would, as Sanctorius affirms.

The Ancients affert, that a pure, dry, cold, and light Air promotes Perspiration, increases the Appetite, and strengthens the Body. But the Air is certainly heavier at that Time, since the Mercury in the Barometer stands at twenty-eight Inches, when the Air is of a moderate Weight; but if the Cold becomes very intense, the Mercury rifes an Inch higher. Since therefore the Weight of the Air is increased one twenty-eighth Part in very cold Weather, our Vessels being more compressed will contract more strongly, so as to act with the twenty-

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when the Ancients speak of a heavy Air as pernicious, they understand a foggy or cloudy Air, which is lighter, as appears from the falling of the Mercury, which is the lowest before Rain, when the whole Air is filled with the pendulous Clouds. But the Ancients were destitute of the Instruments necessary for these Experiments.

§. 431. But every thing of a contrary Nature to those before-mentioned, as also an Increase of all the other Excretions, either diminish, stop, or deprave this insensible Discharge.

Such as purging of the Bowels, &c. For it is a great and epidemical Error, to imagine the Parts to be in a healthy State, when the Fæces are discharged from the Bowels in a fluid State; and from whence many are falfly perfuaded, that the Body can become lighter no other Way than by this gross Evacuation. For in this Discharge by purging, the equable Motion and Diffribution of the Humours is disturbed throughout the whole Body, infomuch that one Pound of Fæces evacuated in a fluid State from the Bowels occasions two Pounds to be retained, which would have otherwife perspired, whence the Body becomes more heavy than if no fuch Evacuation was used: nor ought Purges to be used, unless the Seat of the Disorder is in the first Passages, or unless the Motion of the Humours is to be diminished. But it ought not to feem strange, that Perspiration should exceed the other Excretions, for the Extent of its fecretory Organ is the largest of any, no smaller than the whole Surface of the Body itself; whereas Y 2

the Urine is separated only from the Kidneys, the intestinal Fæces from the Cavity of the Intestines, and the Mucus of the Nose is secerned by the Membrana Schneideriana. In short, all the other Excretions are confined to single and smaller Parts of the Body.

§. 432. From hence we may be able to understand the Kind of Matter 1 composing this perspirable Humour, as also the Causes 2, Effects 3, Necessity 4, and Uses 5 thereof; more especially for promoting the Sostness and Flexibility of the Parts, and for restoring their lost Substance: but it more especially serves to render the nervous Papillæ moist, lively, and apt to be affected by Objects, as well as to remain always ready to carry or transmit the Impressions of those Objects to the Sensorium.

We are not to understand Sanctorius as if the perspirable Matter was derived only from the Food or Aliments; for that was an Error or Overfight in him. He fays indeed, that after taking eight Pounds of Food and Drink, within twenty-four Hours the Body will return to its former Weight; and of the eight Pounds of Aliment three only will be discharged by Stool, Urine, Spittle, Mucus of the Nose, or all the other sensible Excretions put together; and that therefore of confequence, the other five Pounds must have passed off by Perfpiration. But it does not appear that he intends the fivePounds of perspirable Matter discharged from the Body, was derived from the Aliments only; but that for five Pounds of Aliment retained, a like Quantity is perspired or exhaled from all the Pores of the Body, either from the alimentary Juices, or from

from the animal Humours before in the Body. It feems much more probable that fuch Humours which had been highly attenuated, should be capable of passing through the exhaling Pores, rather than the thick or viscid Matter of the Food. Ale, Bread, Flesh, &c. which have not yet been duly attenuated, should exhale in the Form of invisible Vapours, or be so highly subtilized within the Space of a Day, as to pass off by insensible Perspiration. This can by no means be admitted, and even Water itself is not believed to be perspirable immediately by the modern Physicians. Dogs fmell out their Masters by a very small Quantity of the perspirable Matter. I saw a Dog at Amfterdam having loft his Master in a Crowd of People, was therefore obliged to run about continually after the Steps of his Master 'till he came to the House in which he had taken up his Residence. There are therefore some Particles in the exhaling Matter peculiar to every particular Person, by the Scent of which the Animal can diftinguish one Man from all others; but this can never be expected from fimple Water.

The Cause is a high Attenuation of the Humours, pervious through all the Series of Vessels by the Force of the Heart and Arteries, by which also the Humours are expelled through the pervious Vessels, after having been sufficiently attenuated by the Vis Vitæ: and these Causes continuing to attenuate and divide the alimentary Matter, it is at last discharged through the Skin in

the Form of infensible Vapours.

The Effects are 1. To evacuate the Matter which has been first attenuated by the vital Powers. 2. To relieve the other Secretions; for when more Matter exhales through the Skin there is less discharged by the other Emunctories. When the Y 3 Skin

Skin is relaxed the Bowels are constipated, says Happocrates, 3. That the Matter brought last to the Vessels of the Skin may meet with transmitting and excretory Ducts; for if the Matter of Peripiration was to be confined in the Body, it would swell in all Parts to an immense Bulk, and the Vessels would resist the perspirable Humours which were to be last evacuated.

Namely, to discharge from the Body what-

enough to pass through this Emunctory.

It ferves to render the Skin and all other Parts of the Body flexible; for that the Body might be moveable it was necessary for it to consist of very minute Vessels, capable of admitting only the most fubile Humours. Besides this it was necessary for the Body to be sensible in every Point of its Surface, and therefore it is covered all over with nervous Papillæ. But the Papillæ when dry grow rigid and become callous; the Prevention of which could not have been effected by the Vessels which run betwixt the Papillæ: but it was necessary for a very thin Liquor to be secerned under the Cuticle, by which means the Papillæ and whole Surface of the Skin are continually moistened as it were in a vaporous Bath, so as to remain susceptible of Sense and Motion. Hence therefore the perspirable Matter must remain some time in the Extremities of the Veffels before it passes quite through them; and that the perspirable Matter does remain or helitate fome time under the Cuticle, may appear from those Tubercles which arise in the Surface of the Body, by the fudden Contact of the cold Air; which cannot be well ascribed to any other Cause than a Constriction of the Pores or perspiring Ducts, by which the Matter is confined. But in those Animals where the Skin is rigid, as in

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the Rhinoceros, Elephant, &c. which have little more of their Body flexible besides the Snout and their Legs; in these the Perspiration is but small, while the other sensible Evacuations by Urine, Stool, &c. are very copious.

§. 433. From hence we may understand that by increasing the Evacuation of Sweat (§. 425.), and by enlarging the sudoriferous Vessels, Perspiration will be necessarily diminished by compressing the smaller exhaling Vessels.

Also that by violent Motion and too great Heat 2, this perspirable Matter is turned into Sweat.

Whereas by moderate 3 Exercise, and moderate Warmth, the insensible Perspiration is very much promoted.

Also that nothing is more conducive to promote this insensible Evacuation, than gentle

Frictions 4 continued for a long time.

That Sweat continued to Profusion for too long a time, relaxes and weakens 5 the whole Habit, with a Sense of Lassitude or Weariness.

Why this sensible Evacuation happens more frequently to weak 6, phthisical, and consumptive 7 People; as also to those who faint away or are dying, in which Cases Sweats always happen as a necessary Consequence.

Why Perspiration is the smallest immediately after 8 a Meal, and a long time after 9, or before the next Meal, and this even in a heal-

thy Person.

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Why Perspiration is the largest from the fifth 10 to the tenth Hour after Dinner, or any other Meal.

Why riding on Horseback, or in a Coach, as also sailing in a Boat, together with violent Exercise upon the Ice 11, or in the Snow, so greatly promote this insensible Evacuation.

The fudoriferous and perspiring Vessels are contiguous to each other, so that when the former are dilated, the latter must be consequently compressed or diminished; and besides this, the perfpiring Veffels are naturally more compreffible with a lefs Force, fince they are lefs, and composed of thinner Coats than the former. So often therefore as the groffer Humours are by violent Motion or Exercise more strongly urged through the larger Vessels of the Skin, so often will the smaller exhaling Veffels be compressed, whence the Perspiration will be diminished; nor can the smaller Vessels be dilated, until the larger ones are first compressed. For the Motion of the Blood is greatest in the Arteries, and fmallest in the Veins; whence it happens, that in the most ardent Fever the Skin perfpires little or nothing: even the more violent Exercifes and warmest Medicines are so far from increafing Perspiration, that they diminish it; since they impel the red Blood into the smaller Vessels, which are impervious to fuch gross Particles, whence the other finer Juices are excluded from entering their proper Vessels. Add to this, that by Sweat are evacuated those Humours in a thick and viscid State, which if they had continued in the Body, might have been so far attenuated by repeated Circulations, as to pass off by insensible Perspiration. And for this Reason also the infenfible

fible Perspiration is diminished, namely, because the proper Matter is not supplied to the exhaling Vessels. In short, the small Vessels are dilated by Heat and Motion; and when dilated, they do not transmit the thin perspirable Matter, but discharge Sweat: but Sweat differs from perspirable Matter. fince the former is yellow, faline, and fœtid; whereas the perspirable Matter is destitute both of

Colour, Smell, and Tafte.

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<sup>2</sup> I went into a Sugar-baker's Workhouse at Amsterdam, in which they are obliged to use a great Heat to dry the Loaves; to which Heat the Workmen being accustomed, they supported it well enough; but yet I not being accustomed thereto, was not able to fustain the Heat for above three Minutes before the Sweat ran down me. Berneir, in his Journey made with the Mogul's Court into Cacheir, writes to his Friend, that in ascending the Mount Bember, which rifes freep from the Plain of Indostan; "I melt away, says he, in "Sweats; I drink to no purpose, for the very " next Moment I am equally as hot and thirsty as: " before."

3 In Sleep the Humours are equably distributed through the Arteries and Veins; whereas in the Time of a Person's being awake, their Distribution is unequal, more Blood being impelled into the Arteries when the Body is exercised, and more collected in the Veins when the Body is at Reft. Hence therefore in Sleep the Circulation is more equably and perfectly carried on, while the vital Powers are at the fame time more advantageously applied; by which means the Humours are fooner attenuated, and all the Vessels render'd freely per-The fame also follows from moderate Exercise, which comes between Rest and hard Labour, by which the Arteries are fo filled, and the Veins

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Veins are fo moderately emptied, that neither of those Vessels are too much dilated. If these Causes are increased, that is, if the Blood is moved more impetuously, the larger Arteries will then be diffended, so as to compress the perspiring Vessels; and sometimes the sanguiferous Arteries become fo turgid, as to force their contained Blood ino the ferous Vessels, which is also a manifest Consequence from the drinking Also in a slight Fever, if the Matter is not discharged by a plentiful Perspiration, but is faddenly checked or suppressed, it may settle or stagnate in some Parts, and form scirrhous Tumors. If Exercise is not followed, then the Humours are not fo well attenuated, and consequently they will not be perpetually impelled through the smaller Vessels. It is therefore evident, that a Medium is to be followed betwixt these two Extremes, of violent Motion, and too great a Reft of the Humours; and it is also evident, that Fevers may as well arise from a Suppression, as from too great an Increase of this Evacuation.

\* Galen had so great a Dependance on and esteem for this Remedy, that he has wrote a whole Book concerning Friction. The Ancients after placing the Person in a Stove, rubbed the Skin with dry rough Cloths made warm, by which means they highly attenuated the Humours, and at the same time increased the Power or Action of the Vessels; and by these means Perspiration may be restored after it has been a long time suppressed. I even lay very little Stress or Dependance upon any other means in chronical Disorders. I had under my Care a young Man whose Abdomen selt so hard and distended to the Touch as if it contained Pieces of Wood; but yet I restored this Patient to a persect State of Health by

a constant Use of Mead, with the Use of Frictions repeated every Day. But the Measure of the Friction is to be determined by the Return of the natural Heat, for if it be increased beyond that, more or less of a Fever is produced.

Sweat if it is not critical weakens the Body in all Diforders, because it evacuates the useful together with the excrementatious Humours; for since the more subtle and gross Juices will be expelled together, the nutritious Juice with the nervous Fluid or Spirits will escape together. Besides this, too much Sweat interrups or weakens the continued Pressure from the Heart to the smallest Arteries in the Encephalon; and from hence Weakness and

Faintings follow.

6 Those who are afflicted with an acute Fever. have their Skin always dry; but when Death approaches, a yellow, fætid, viscid, and cold Sweat appears all over the Body. In this Cafe then all the minute Valves which cover the Mouths of the fudoriferous Vessels, with all the cutaneous Sphincters are relaxed, and from hence the Humours which were before accumulated in those Vessels meet with a ready Discharge after the Resistance is taken off. For it must be observed, that not only the Mouth, Eyes, urinary Bladder, &c. are provided with their proper Sphincters, but even every Veffel and Part of the Body have a contractile Power, by which they exclude every thing injurious. When a Person is invaded with the Plague, he perceives a Senfation as if cold Water was poured over him, whereupon all the cutaneous Sphincters are contracted: but it is also, from a Relaxation of the Sphinoters, that dying People often evacuate their Urine and intestinal Fæces infentibly, at the fame time when these Sweats appear. But these Sweats are cold from the Stagnation

nation of the Matter without the Course of the circulating Humours, and from the Weakness of

the vital Powers.

One principal Action of the Lungs is to compact the thin Blood into dense Globules; for when the Lungs are injured, or their Function impaired, the Chyle then retains its crude and watery State, and all the Humours melt away and run off by the several Emunctories (§. 204.) Hence riding on Horseback is a kind of vicarious Remedy to answer the Office of the Lungs upon the Blood. For when a Person rides against the Air, it has the fame Effect upon the Lungs as if the Air was render'd heavier; for it is the fame thing with respect to the Lungs, whether the Air be made four times heavier, or moved four times more swiftly into the Lungs: to which add the infinite Number of Succustions, by which the Blood is struck against the Sides of the small Vessels. This Exercise was the great Secret of Sydenham, which I have happily experienced in many Patients.

Namely, at that time when the Chyle is as yet thick and crude in the Blood, not being attenuated or subtilized to such a Degree, as is necessary for it to pass off in some measure by insensible Perspiration; the whole Effect of which is produced by the vital Powers. Lower assures us, that Digestion is not finished before the fifth Hour after a Meal (§. 87, 129, 204.). Besides this, the larger Vessels are at that time more turgid, while the smaller Vessels are compressed; this Truth we are assured of from the Experiments of Sanstorius. From whence it appears, that scarce more than twelve Ounces are perspired during the first three Hours after a Meal, whereas within five or six Hours from the first, the Body is found to be two

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This follows from a Consumption of the Humours, which when profusely wasted or consumed, occasioned the Vessels to lose their contractile Force, whence the Blood cannot be sufficiently attenuated to prepare and discharge the perspirable Matter. Those who perish with Hunger do not expire for want of the grosser Humours, since the larger Vessels are sound replenished with Blood, but they perish for want of the more subtle Humours, and from a Collapsion of the smaller lateral Vessels through Inanition.

and converted into Milk; but by the twelfth Hour it is turned into Serum, which is thin enough to exhale in a great measure, or at least to supply the Place in the Vessels of those indigenous Humours which have been exhaled from

our Bodies.

Perspiration is this way so much promoted, that in three Hours time, the Evacuation amounts to the same as fix Hours Exercise in a hot Air. For the cold Air constringes the Vessels, that only fuch Humours can escape as are the most fluid: and at the fame time the increased Action of the Body augments the Power and Reaction of the Vessels upon the Juices; so that if Exercise to a considerable Degree be joined with these Circumstances, by the greater Attrition which is produced betwixt the Vessels and their contained Humours, a considerable Heat of the Body will arise even in the midst of a cold Air; and from hence those Humours which are the most attenuated, will be urged through the Pores of the Skin, and carried off by the Air. And this Evacuation is sometimes fo much increased in a short Time, that by interrupting the continued Pressure of the Humours towards the Encephalon, a Fainting, and Death

Death itself at length follow. Even in Holland there are not wanting Instances of the voracious Appetite or Bulimy, especially in the Northern Parts. When Persons have been scating upon the Ice very fwiftly for a confiderable Time, they have been known to sweat profusely, even in the midst of the Snows; infomuch that they have fell down fuddenly, panting with their Mouth open, and in a Swoon, and in a short Time after they have expired. It is usual in these Cases to give spirituous Liquors to the Patient, which must be in Effect as bad as Poison, since it too suddenly diffuses itfelf. and by its spirituous Nature exhales together with the more subtle Humours. Such People ought to be nourished with the most compact Aliments, which are not eafily attenuated but by a confiderable Action of the vital Powers: fuch are brown Bread that is very folid, Fish and Flesh falted and dried in the Smoak, &c. And by this means the too great Action of the Solids upon the Fluids may be easily supported; hence Hippocrates observes, that in Winter time the Venters or Viscera are warmer, and therefore an Addition is to be made in the Aliments.

Of the Nutrition, Growth, and Decay of the Body.

§. 434. O render the human Body capable of duly exercifing all the Motions 1 of the Humours, Vessels, and Muscles without deftroying them, it was necessary for the several Vessels, Muscles, and Fibres 2 bility, the cohering Particles ought partly 4 to change their Contact, and partly to remain or continue in their Contacts with each other. But this Change could not be performed, unless the larger constituent Parts of the Body were made up of the most flender 5, fine, and short Threads, composed of minute Particles; nor even then could those Actions be performed, unless a Humour 6 continually passed betwixt the smallest Fibres and Vessels to prevent their Concretion, and restore such Particles as are lost; the whole Body therefore, as a slexible Machine adapted to various Motions, ought of necessity to consist of small Vessels 7.

The human Body could not have been made fo as to answer all its Offices, if its Matter was the most rigid Adamant, or its Parts one continued Statue. For as the Body is made up of innumerable small Machines, each of which have their particular and different Motions affigned to them, it was necessary that the whole Machine should be composed of such small Parts, or more fimple Machines, as might each of them perform a proper Motion, in fuch a manner, that though the Actions of each are different, yet that they might receive their common Principle of Motion from one general Cause; and thus are they conjoined into one Machine; for all Difeases and Pains are perceived but by one and the fame Mind, as are all the Motions or various Actions of the several Parts derived from one common Mover, which is not only sufficient to continue the various Works of the whole Machine for a **fhort** 

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short time, but even for the Space of a Century and half, notwithstanding the Machine is by various Accidents frequently destroyed before that For Men of Letters spare their Bodies, and confume or spoil their Brains, while the Husbandman spares his Intellects, but renders his whole Body rigid and callous too early in all its finaller Parts by hard Labour; while other People again Subvert and disturb the several Offices of their Machines, fo as to haften the Destruction of the whole, either by too much Reft, or too much Motion of the Humours and Vessels, by Errors or Excesses in the Non-naturals, especially by Intem-

perance in Diet, &c.

2 The Bones of the Shoulders or Arms, with those of the Fore arms, the Radius and Ulna, are fo connected to each other, that they conform a right Line together, or be inflected upon each other fo as to describe various Angles; but only let the Mucus confined in the Capfules of the Articulations be dried up and concreted, the whole Limb will then become rigid and immoveable like a Stick; whence it appears, that for the human Body to be moveable, it was necessary for it to confift of many diffinct Parts; and in general, the greater Number of Motions there are to be performed by any Part, the smaller are the constituent more simple Parts, which compose the whole.

3 We call a flexible Body one whose Parts so cohere together, that they may be changed into any Posture without breaking or dissolving their Continuity, or mutual Contacts. But the feveral Parts of the human Body were required to be fuch, as to admit the Vessels to be dilated and contracted in various Degrees, and for the Muscles to act in various Directions, &c. There is not even a Nerve, Muscle, Gland, or other smaller

Part of the Body, capable of performing its Office when it has once become rigid: but the feveral Parts of the whole ought to be flexible in every Point; for if a right Line is to be changed into a Curve, or a Curve into a right Line, the smallest Points or right Lines which compose the Curve must each of them change their Situations; and from hence again it is evident, that the several Parts of the human Body were required to be not only flexible, but to be made up of the smallest Particles all of the same Nature.

4 Let us take, for Example, two Loadstones; if the same Poles of each Stone are applied together, they will cohere and form one continued Body; but yet their Cohesion will not hinder them from moving freely, or bending either way, even without destroying their Cohesion. In the same manner two Elements, or primary constituent Particles, may be conjoined into a small Fibre, so that it may be bent in any Direction without removing the Particles from their mutual Contacts with each other; and this is that Flexibility which does not reside in the Elements, or constituent Particles of the smallest Fibres, but in their Connection or Cohesion to each other.

the other, they may remain flexible; but when feveral Rows of fuch Bodies lie Stratum fuper Stratum; or, which is the fame, if groffer Particles are collected together into one Fasciculus, they will not then be so perfectly flexible, notwithstanding their Flexibility will continue, though not so free in every Part. If you suppose several right Lines lying by the Sides of each other, it may be easily conceived that some will be more flexible than others, because the lowermost will be formed into a smaller Arch, while each of the upper ones

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describe larger Arches; so that there will be Ar ches of several Derrees, in proportion as the Distance is greater from the Center of the Inflection to the Circumference, in which the Circles of the inflected Lines are the largest. From this Consideration we may explain how a Body may be itself inflexible, when at the fame time its constituent Parts are all of them flexible; and how a very brittle Body may be render'd flexible. Even Glass itself, which is so extremely brittle, being drawn out into a hollow Thread smaller than a Hair of one's Head, is eafily bent or twifted round any thing, only because of the great Thinness of such a small capillary Tube, and therefore there are but very few Strata of the vitrious Particles lying upon each other: but if many of these very flexible Threads of Glass are collected together into one Fasciculus, perhaps of a thousand, some of them will remain whole, while others are broke, after endeavouring to bend them. A Cable Rope is rigid and inflexible, notwithstanding it is composed of very flexible Threads. Hence therefore it is evident, that the greatest Tenuity and Flexibility are joined together in the fame Body purely from the natural Disposition of its Parts: and it is also evident, why the Creator has composed our Bodies of the smallest Fibres.

This is a common Property of the Fibres of a human Body, namely, that if one comes into Contact with another without the Intervention of a Fluid, they immediately cohere together. If an Ulcer has confumed Part of the Fingers, and the naked Surfaces of the two Fingers are applied and retained together by Bandage, they will grow together within the Space of a fingle Night. Sore Eye-lids and bleeding Lips do likewife eafily grow together, unless they are cautiously prevented.

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The Canalis Arteriofus, Venofus, Foramen Ovale, with the umbilical Vessels, though large Tubes of a confiderable Diameter, do nevertheless grow together fo foon as the Blood ceases to flow through them in the new-born Infant. But if this happens in the larger Vessels, how much more readily will it fucceed in the fmaller ones? But if feveral fmall Fibres are conjoined together into one Thread. they cannot be separated by the Interposition of any Humour, unless the large Thread itself is hollow: and therefore those Threads which are made up of the smallest and most simple Fibres, must necessarily be hollow; but if the Cavity of such a fmall Vessel, composed of the minutest Fibres, is obliterated by Labour, old Age, or a Denial of the Juices passing into it, the Flexibility, Motion,. and Use thereof is destroyed by the Concretion of its Sides.

<sup>7</sup> But it was not only necessary for the several Threads of the Body to be formed pervious, but they were also required to be separated from each other by the Intervention of Juices flowing through them; for the smallest Vessels and Fibres grow together, as well by a Stagnation of their contained Humours, as by a Collapsion and Vacuity of If the Blood stagnates but a small time, it congeals into a folid Mass, and coheres with the Sides of its containing Vessels. If the Blood stagnates but a small time in the Aorta, as it does in those who are subject to Faintings away, there are very often Polypus's found after Death adhering to the Sides of the Heart; and therefore the Humours ought to flow freely betwixt the Sides of the smallest Fibres and Vessels. But the Motion of all the Humours in the Body is derived from one common Mover the Heart, to which the larger Vessels are immediately continuous: but from the  $Z_2$ 

larger Vessels arise the smaller ones, which diminish in several Orders down to the most minute; and therefore the Humours are moved through the Cavities of the smallest Vessels by the Force of the Heart.

§. 435. But this very Motion being continually 1 and violently performed in Vessels of fuch a tender 2 Fabric, must necessarily occafion the smallest Parts to be broke or rubbed off from the folid Fibres by the continual Impulse of the Humours and Actions of the Muscles; which abraded Particles mixing with the Humours, are at length circulated together with them, and discharged from the Body mostly in the Form of Exhalations; in the mean time the Fluids being continually leffened, or ground small by Attrition, are at length propelled to the exhaling Vessels, and evacuated from the Body; and from hence the living Machine of the Animal foon 3 destroys itself from the very Condition of its Frame.

The feveral Juices which are moved through the Vessels of the human Body, must necessarily cause a great Attrition. The celebrated M. Amontons, in a Treatise concerning the Attrition of moving Bodies, has demonstrated that the Friction of Bodies moving upon each other, is a very great Impediment in Machines, so as to equal almost a third Part of the Weight to be moved. Mem. Acad. Reg. 1699. p. 257. Since therefore there are above seven thousand times two Ounces of Blood expelled from the Heart into the Arteries in an Hour, it

is easy to conceive that the internal Sides of the

Vessels must be abraded, or wore away.

<sup>a</sup> A fanguiferous Vessel, which is the largest of the smaller Vessels, is no thicker than the tenth Part of a Hair of one's Head; but then there is an incredible Diminution or Distance betwixt the largest of the smaller Vessels, and the very smallest of all, fince the Diameters of the decreasing Series of Vessels are continually answerable to the Particles of the Humours which are to flow through them; fo that there feems to be an infinite Number of Series interposed betwixt the smallest fanguiferous and pellucid Veffels. But yet it is necesfary for Humours to be contained in those small Veffels, which Humours must also pass swiftly through them to prevent their Concretion. But how minute or fine are these smallest Vessels, if we confider the Subtlety of the Juices which flow through them. The Brain itself, which is entirely a Compages of small Vessels, is so tender, that it may be divided by a Blast with one's Breath, after the Pia Mater has been taken off; and therefore if you compare the perpetual Motion of the Humours with the exceeding Minuteness and Tenderness of the Vessels, it will apparently follow, that some of the constituent Particles of those Vessels must be continually abraded and carried away by the refluent Humours. But fince the largest Vessels are not only pervious to their contained Humours, but are also composed of smaller Vessels, they will therefore consequently be destroyed both by the Action of themselves, and of the small Vessels ot which they are constituted. Unless therefore the Body is continually supplied or nourished with the other Particles, to fill up the Places of those which were abraded, the Body will foon perish. Even a small Vessel, which in the last Series seems to be perhaps

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perhaps a thousand times smaller than a Hair of one's Head, is perpetually destroyed, and again regenerated. But these constituent Particles, or Elements of the Solids, abraded from the smallest Vessels, and reduced to a fluid State by Attrition, certainly make a large Portion of the perspirable

Matter of Sanctorius (§. 432.)

3 Thus the Body naturally destroys itself from its own Nature; and the Animal no fooner begins to live, than to approach towards Death, which is the Consequence of Life. The greatest Period of Life is a Century and a half; but from what has been faid before, we may understand why Persons are more liable to Difeases and Death, as they are younger or nearer their Birth? for more perish in the first Month of Life than in the second, and more in the first Year than in the second; for the Strength and Permanence of the Body increases with the Age. I made use of this Argument to keep up the Spirits of an old Man of ninety Years, who was afraid of Death without any Reason.

§. 436. It is therefore necessary 1 for the due Continuance of Life, and the Maintainance of the feveral Parts of the Body in their found or natural State, that as much, or as many of the same Kind 2 of solid and fluid Particles should be perpetually restored, as are continually wasted by the several Actions of Life; and this Restitution is called Nutrition 3.

From the Age of twenty-five to fifty Years, the human Body receives scarce any Alteration, but as every Day a large Part of its Substance is confumed, some Addition must be necessarily made to restore the lost Substance, namely, almost the whole Substance of the Bread and other Food, except the Bran and groffer Parts is converted into Chyle, Milk, Serum, and Blood; but Serum in the Space of twenty-four Hours is fubtilized to a very great Degree of Tenuity, in the fame Manner as the white of an Egg is so highly attenuated within a certain Space of Time, as to be capable of nourishing the incipient Chick; and of the fame Nature with the attenuated Albumen of the Egg, is that Juice which repairs the wasted or lost Substance of the Body.

Thus Sanctorius affirms, it is necessary for the Body to be supplied continually with as much Matter of the same kind as is continually consumed or carried off from the Body. He that can perform this one Point, is acquainted with the Art of preserving the Body immutable to extreme old Age; but if more is added to the Body than is consumed, it will be oppressed or overloaded; if

less is added, the Body will waste or decay.

<sup>3</sup> The Restitution of the lost Substance in the Body is twofold, the one by which the folid Parts are repaired, and the other by which the exhausted Juices are supplied: for in the Juices, as we before observed, there are at least five Pounds lost by Perspiration in a healthy middle aged Man in the ferene Air of Venice. But the folid Parts of the Body are also abraded or worn away in so much a larger Proportion as the Parts are exercifed with a more violent Motion. If the Urine of a Horse which has stood idle for some time in a Stable, be viewed with a Microscope, you will perceive small Spiculæ floating in it; but if the Urine of the same Horse be at another time examined, after he has been well exercised or fatigued with Labour, those Spiculæ or folid Corpuscles observed floating in the Urine will appear a hundred times more numerous; from whence it manifeftly appears, that by muscular Motion or continual

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tinual Exercise of the Body, many of the solid Parts are wore off from the Fibres and Veffels (§. 379.) But how long a time a Man may live without Aliments, may appear from the notable Instance of a noble Captain in our Army, who being weakened by the Wounds which he had received, lay among the Dead for the Space of three Days and Nights, 'till on the fourth Day a Woman who came to make Spoil of his Cloaths, &c. perceiving some Motion in the half dead Man, carried the News to the Camp, and he was by proper means recovered; from which time he has furvived for the Space of forty Years to the Advantage of the Republick. But this is nothing in comparison with the Histories we have of Abstinence or Fasting continued for several Months or even Years.

§. 437. The Humours which are confumed or exhausted, are again supplied as to their Matter by the solid and sluid Aliments, as also in part from the external Air; but as to the necessary Qualities of that Matter, those are produced by the concurring Powers of the several Parts of the Body which we have hitherto explained, by which the nutritious Matter is formed and applied by the respective Vessels: and this is what we are to treat of in this Place.

The Nutrition or Restitution of the sluid Parts of the Body consists in the Air, Water, and Juices of Vegetables and Animals taken into the Vessels, depositing their own Nature and acquiring that of human animal Fluids; that is, for them to change their Nature so as to be converted into Blood, Serum,

rum, Lymph, animal Spirits, &c. and Nutrition is then compleated, when so much of every Class of the Humours is restored in Proportion to the Loss or Confumption which is daily made in each by the Actions of Life. Thus the ingested Aliments are first changed into Chyle, the Chyle into Serum and Blood, and the Blood itself into the feveral Orders of more fubtle Humours, which are prepared in the feveral Parts of the Body. But we are not to imagine that Repletion and Nutrition are the same; for by Repletion we understand an Accumulation of fo much Matter as was exhausted from the Body, whereas Nutrition respects not only the Quantity but the healthy animal Qualities of the fame Matter; that is, when the Body retains its proper Weight, but the Juices continue in a crude State without being properly affimilated Thus after a profuse into healthy animal Juices. Hæmorrhage, it is no difficult Matter to render the Body of the same Weight, by filling the Veffels merely with Water or watery Liquors; but this Repletion of the Vessels does not repair the Functions of the human Body, to do which the Blood alone is adapted; but the whole Body becomes weak and unactive, the Juices retain their crude or indigested State, and the Water escapes and stagnates in the smaller Vessels and Cells of the Body, whence a Cachexy. And in general, if the Body is destitute of Strength, whatever Aliment is taken in does not nourish, but remains crude or indigested. And from hence we may understand how injudiciously Infusions and Transfusions of Blood and other Liquors have been abused by Physicians, upon little or no Foundation for repairing the vital Powers of the Patient. The bad Success of these Experiments in France, England, and Germany, is fufficient to demonstrate, that every

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Blood, and that one Man or Animal cannot receive it from another so as to reap any Advantage. But if to a Person who is thus pale and bloodless, we give Bread, Milk, and Flesh Broths in small Quantities, and at frequent Intervals, both the Flesh-Broths and Bread will then be converted into the healthy vital Juices of the Patient by the Powers of Life, or the Actions of the several Organs which we have hitherto explained, whence a true Assimilation or Nutrition will follow.

- §. 438. But the Nutrition or Restitution of the solid Parts, though something more obscure than that of the Fluids, is yet intelligible from a Knowledge of the following Particulars.
- §. 439. Every solid Part of our Bodies is composed of other 1 lesser Solids exactly resembling the larger; the Vessels are made up of smaller Vessels 2, the Bones of smaller Bones, the Muscles of smaller Muscles, &c. which Course is continued in the Composition of the Parts even beyond the Limits of Sense, assisted by what Art soever, as we are assured from the accurate Experiments of Malpighi, Ruysch, Lewenboec, and Hooke. But yet this Division scarce proceeds in infinitum 3, as appears by the Nature of the Humours and alimentary Juices.
- Vein of small Veins, the Nerves of smaller Nerves, and the Muscles of still smaller Muscles, &c.

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2 The largest of the Vessels in the human Body is the Aorta among the Arteries, and the Vena cava among the Veins; though the last, together with the Heart, are rather Receptacles. But the large Artery, called Aorta, is composed of feveral Membranes, which receive fo many Bloodvessels from the coronary Arteries, that within the Compass of an Inch of its Membranes there are more than a thousand Myriads, each of which are diftinguishable to the naked Eye, after they have been injected according to the Artifice of Ruyleb: infomuch that the whole Artery feems to be composed, not of Membranes, but of mere Vessels interwove together, much after the fame manner as fome fort of Stuffs are wove of flexible glass Tubes, which are extremely minute; for the ductile glass Threads are always hollow. Such an Intertexture very much refembles the Membranes of our Bodies. of which the Vessels themselves are composed. Nor are the fanguiferous Arteries themselves only vascular, but all the smaller Series of Arteries are likewise composed by an Intertexture of others still fmaller down to the very laft, which not being vascular is composed of a mere simple Membrane.

There have been some Geometricians of Note, who have afferted that this Division was infinite; and indeed it is true that it escapes our Senses, nor can we penetrate to the End of this Division by the Help of Microscopes, Injections, Putrisactions, or Dissolutions of the Parts; neither of which will conduct us to the smallest Elements, or constituent Particles of the Body. Hartsoeker has informed us of an Animal no larger than the hundredth Part of a Grain of Sand, which lays three hundred Eggs; and in general it is observable that Insects are the more prolific, as they are more minute. But how small must be the Vessels in such

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a minute Animalcule? But the Particles of the Blood are of a determinate Magnitude; and the leffer Particles which follow in feveral Orders to the red Globules, are each fix times less than the other; so that the Particles or Globules of the thousandth Order will be to a red Blood Globule, as the Power of a Fraction of a thousand by is to Unity. But the Division must necessarily stop somewhere, fince the human Body is a limited Being, and fince we find that the Magnitude of the Vessels is determined, the Aorta being the largest; and as a Person is soon refreshed after being fatigued by Labour, barely by the Assumption of a moderate Quantity of Aliments; whereas it does not feem probable that the Aliments could be divided into fuch minute Particles in fo short a time, as to correspond to such infinitely small Vessels.

§. 440. But Microscopes 1, Injections, the smallest Wounds, blistering Remedies, Consumptions 2, and a withering of any Part inform us, that our Solids are but a very small Portion in comparison with our fluid Humours; even it is almost demonstrable, from considering the Origin 3 and Formation of the Vessels, and from resolving the larger Vessels into the smaller ones of which they are composed, that the solid Mass of the whole Body is almost wholly composed of mere Nerves 4, which lay the first Basis of the solid Elements or smallest Threads of the Body.

If any Part of the Body be examined by the naked Eye, it feems to be a mere Solid; but yet in such a small Particle of the Body, no larger than the hundredth Part of a Grain of Sand, the Microscope

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croscope demonstrates innumerable small Vessels, each filled with their respective Juices (§. 214.)

It is almost incredible what a small Portion of the Body is composed of mere Solids. If we subtract from the human Body all the Cavities, Veffels, and Receptacles, together with all the Juices. there will then remain so small a Portion of a solid Mass as to be almost inconsiderable. In a Horse that appears in good Condition almost half his Body is mere Fat (§. 396, 416. No. 4 and 5.); and by fattening he may acquire almost as much Weight again. If you take a very fat Ox to the Plough and exercise him with unusual Labour, he will become so lean, that after taking out the Stomach full of Grass, Hay, or other Food, with the several Viscera, which increase the Weight of the Carcass without being properly a Part of it, he will be reduced to the tenth Part of his former Weight; but if fuch an Ox reduced to the last Degree of Poverty be put up in the Stall to feed and reft, he will recover his former Weight. I have observed strong muscular Men with large Limbs, who after falling into an Hæmoptoe or a Confumption, have been so much wasted, that they have retained little or nothing of their former Bulk, their Bones being but loosely covered by the Skin, through which the Thigh Bones might be easily felt, when at the fame time no Part either of the Vessels or Muscles was destroyed, only their Juices exhausted. Even the Bones themselves which seem so compact and hard, lose almost all their Weight after they have been calcined in the Fire, and deprived of their Juices and Fat. Men who have gradually corrupted for many Ages in Sepulchres, feem at first Opening of them to retain their former Shape, but they are no fooner touched, but the whole Figure of the Man falls into a small Quantity of Duft.

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Dust. After Alexandria was taken, Cafar, who was afterwards Augustus, had the Curiofity to visit the dead Carcass of Alexander of Macedon; he indeed faw him in his Coffin, but was shocked to find the Conqueror of the World fallen into a finall Quantity of Dust or Ashes. We have several accurate Experiments made in this respect by Keil. He used a Balance like that which Mr. Boyle has depicted in his Hydrostatics, and such as they make at Amsterdam, which I have fometimes bought at the Price of an hundred Florins; this kind of Balance is fo exact that the hundredth Part of a Grain will turn the Scale, and cause it to descend. He placed upon such a Balance a Portion of the human Brain, and observed that every Moment it was necessary to add fome Weight to the Scale to maintain it in Equilibrio, fince the Brain grew continually lighter, 'till it was reduced to one twentieth Part of its Mass. Hence therefore it appeared, that nineteen Parts in twenty of the Brain were Fluids and exhaled from it. Nor ought it to be objected that many Parts of the Body appear fufficiently hard to the Senses, for their Resistance is derived chiefly from the Fluids which are contained in the Veffels. Even a Bladder that is very full feels as hard as a folid Body, notwithstanding it was of itself extremely foft and flexible.

One of the principal Observers of Nature, Malpighi, assures us of this (§. 276.). For a Hen which has been separated a Fortnight from the Cock, lays Eggs in all Appearance nothing inserior to those of a Hen which has been lately trodden. After placing some of the former insecundated Eggs under the sitting Hen they putrify in a few Days time, and the Albumen being attenuated exhales through the Pores of the

Shell,

Shell, while the Yolk only remains within the Shell in a putrid State. Hence arises that Suspicion of an Egg being unfound that does not appear full, namely, one whose Membrane in the obtuse End of the Shell has been rarefied or broke. But Malpighi having fet fome Eggs of the fame Hen after being fecundated by the Cock, they brought forth Chickens after twenty one Days, which were fo increased by exhaufting the Albumen, that they weighed heavier than the Egg itfelf, namely, an Ounce or an Ounce and half. In the mean time we meet with one confiderable Difference betwixt a sterile and prolific Egg, namely, that in the Sacculus placed at the obtuse End of the Egg full of crystalline Liquor, there is a small red Point in the fecundated Egg, which is absent in those which are sterile. From that red Point the Carina or incipient Chick begins to be formed within a few Hours; first appears the Medulla Spinalis with two other Points, namely, the Brain and Cerebellum; to which are added, after twelve Hours time, the two Eyes, or a new Pair of small Bladders; and at that time the whole Animal appears to confift of nothing more than the nervous System, without either Heart, Lungs, Liver, or any other of the fanguiferous Vessels. But in a little time after, a kind of Ring is appended by degrees to the Carina, which is contorted at length into four venous Sinus's, which being conjoined together form the Heart, namely, the two Auricles and Ventricles. In the next place, the Lungs, Liver, and other Viscera begin to appear; and this Method is followed by Nature, not only in the Chick, but in the human Species, in which at first there is little more than the Head. to which the other Viscera are added by degrees.

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Nutrition is carried on by the Nerves, because the nutritious Humour is not applied to the Vessels by their internal Surface, but by other smaller Vascules of which they are composed; the smallest or last Series of which are the Nerves; the last Series but one is an Intertexture of the preceeding Order, and so of the rest, which are derived successively from each other. When therefore the larger Vessels are nourished, so must also the smaller, and even the ultimate Vessels, of which the large ones are composed, be likewise nourished; but these ultimate Vessels are small Nerves (§. 302), for a Nerve we call that Vessel which is the smallest or ultimate.

§. 441. And, in truth, all this Mass of the Body, except an incredibly small Particle, grew up from those Humours which were before extremely subtle, namely, the sluid Colliquamentum, which is very much like the nervous Juice, as Malpighi has demonstrated by his repeated Observations in his Treatise de Ovo incubato.

I have a human Fœtus by me no larger than an Ant; and yet from so small a Fœtus, within the Space of nine Months, is formed an Infant weighing seven or eight Pounds: but this Addition of Weight and Matter could be made no other way than by the umbilical Vessels, or from the Liquor of the Amnios. The Humours which enter'd by the umbilical Vessels were derived from the Uterus by Ways as yet obscure, transuding through a Membrane as compact as the Cuticle itself. Both these Liquors must therefore be extremely subtle.

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In the Chick the Nourishment is derived from the thinnest Part of the Albumen, which being slowly prepared, is at length propelled in the Sacculus of the Colliquamentum; and yet from so thin a Liquor are derived, in the Space of twenty Days time, Parts so compact as the Bones, and so tough as the Tendons.

- §. 442. Nor does the White of the Egg nourish before it has been reduced by the Power of Incubation through various Degrees of Fluidity, passing through the different Strata, or concentric Lamellæ, terminating at length in the required Degree of Subtlety; but even then when it's arrived at the Embryo, this Liquor is comparatively very thick, and must be much more highly subtilized in the Vessels and Viscera themselves.
- The true Chick is that Particle imparted to the Egg by the Cock. But in order to unfold and expand this small Point concealed in the Semen of the Male, the Albumen of the Egg only fuffices, and the whole Bulk of the Chick is formed entirely from thence from a very small Particle. But the Albumen or white of the Egg is compofed or made up in the following Manner, which I have always contemplated with Pleasure. In the first Place we meet with the Shell which is of a flony Nature or like Mortar, and though foft one Day is hard and brittle the next before it is excluded. If this earthy Substance be taken off by macerating the Egg in Vinegar, we find immediately under it a tough Membrane, which may be feparated from the rest of the Egg by making a small Puncture in the obtuse End and blowing into it. Aa Within

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Within the anterior Membrane is contained the Albumen and Yolk, which last serves for a Placenta to the Fœtus, and in the Center of the Yolk is the Chick itself. This Fœtus or incipient Chick is invested on all Sides with oval concentric Sacculi, which increase in Diameter in Proportion as they are more remote. The Air which is admitted through the Pores of the Shell being rarefied by the Heat of the fitting Hen, takes up a larger Space, and preffes upon the included Humours: Thus the Membranes are preffed so as to recede from the obtuse End of the Egg to which they before adhered, like the Dura and Pia Mater within the Skull; but the Membranes being preffed, urge the Albumen fuccessively through the concentric Sacculi into the Chalazas which are inferted into the Amnios. In this Filtration or Transcolation the Albumen is rendered continually more fubtle, and is again elaborated in the small Glands of the Yolk, 'till at length it passes partly through the Mouth of the Chick (for in the Stomach of the incipient Chick a true Jelly is always found) and partly through the omphalo-mesenteric Vessels to the Intestines, where being elaborated into Chyle, it is absorbed by the Veins, and suffering all the Actions of the Body, is at length converted into Blood, Serum, Lymph, and Spirits. But fince it is so highly subtilized while contained in its Sacculi, as to be able to exhale or fly off in an invisible State, we may readily apprehend how extremely fubtle it must be, when it is perfected and derived into the smallest Vessels of the Chick. This Tenuity is obtained by a Degree of Heat which is the most favourable to Putrefaction, being much the same both in the sitting Hen and in the Uterus of the gravid Woman.

§. 443. But from this very subtle Humour arise the first tender Solids 1, which are very much like Fluids; from which State they pass through various Degrees 2 of Firmness, 'till they at length compose the most solid Parts of the Body, as we are taught by Malpighi in Eggs, and as hath been demonstrated with indefatigable Industry in Embryo's and Fætus's 3 by Ruysch; and which also appears from the accurate Order or Course of the different Parts themselves. It is therefore from hence apparent, that the solid Parts in their first Origin from the Fluids, from whence they are derived, differ only in the Rest 4, Cobesion 5, and Figure 6 of their Parts.

The Chick which in twenty-four Hours time after Incubation is taken out from the Egg, appears to be no more than a Point, which by a fmall Puncture with a Needle is refolved into a red Drop. But yet in that is contained the Brain, Cerebellum, Eyes, and all the other Parts which we afterwards fee produced: In general, the Experiments made upon incubated Eggs demonstrate, that all the Parts are more fluid as the Animal is nearer its Original; but that they gradually harden, so that on the twenty-first Day the Bones begin to appear in a perfect State, and within the Space of two Years, in the fighting Cock, they acquire the Hardness almost of Iron; even every Part of the Body, let it be never so hard, was at first a foft Jelly.

The Thigh Bone is at first a thin Lamella, and becomes afterwards a thicker Membrane, at length a thin Cartilage, and then a more compact

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Cartilage, within the Center of which the Point of Offification begins, and spreads itself all over the Femur, which is then converted into a hard Bone. There is no Bone in the human Body but what was at first a Cartilage, nor any Cartilage which was not before a Membrane, nor yet any Membrane but what was at first in the fluctuating State of a Liquor. But barely by Motion and Attrition all even the softest Parts of the Body are converted

into a bony Nature.

3 Ruysch had a very beautiful Collection of Foetus's, which is now transported into Russia. And in that incomparable Collection, there are feveral fmall Bodies no larger than Ants, others as large as Pease; and from thence there are Fœtus's a great deal larger in Size, and more perfect in their But even in the least of these there are all the Viscera and Limbs pre-existing, or at least there are all the physical Causes which compleat the human Body; namely, a complicated Canal forming the Heart, with the nervous System, &c. Yet all the Parts are extremely foft, and in a fluctuating State; but from that Softness they gradually pass to a more compact State, so as even to refemble the hardest Stone, as we see in the Teeth, which were themselves but a little time before a Jelly contained in Cells in the Gums, and receive their Nourishment from invisible Arteries; whereas when they appear through the Gums, they are fo hard that a Hammer will hardly make any Impression upon them. Even the Hairs which are fuch fmall Corpufcles, are nevertheless so tough, that if a thousand of them be twifted together into a Cord, they will eafily fustain a thousand Pounds Weight. It is therefore evident, that the Parts of the Body pass through various Degrees of Fluidity Fluidity and Cohesion, till they arrive at the great-

eft Degree of Compactness and Hardness.

A Suppose there are three elementary or minute Particles of a Bone, which are not compound, but as simple as possible, their State will certainly be volatile and fluid, if they are moveable upon each other; but if they rest or cohere together incapable of Motion, they will form a solid Body without any other Alteration. Whence it appears that a

Fluid differs from a Solid only in Degree.

The Reason of the Cohesion of Parts in Bodies is understood but by a few. In general, it is a Power by which the Parts of a Body refift Separation from each other: that is, all the Particles of a Body acquire a more powerful Cohesion, in proportion as they are in closer Contact with each other, being almost infinite when the Contact is the greatest. If Gold be drawn out into a Wire, or fine Thread, by a strong Machine, it nevertheless continues to be the same Gold, has the same Cohefion and Flexibility; nor will the Power of Cohesion and Ductility in the Parts of the Gold cease, as long as Art is capable of drawing the Wire through fmaller Holes. Thus wonderful is the Attraction and Cohesion of the Parts of Gold with each other. But the same Gold which so powerfully cohered before, fly from or repel each other upon making a Division by cutting with a Knife, nor can those Parts be ever conjoined together again: but suppose it separated into a thoufand small Particles, they may all of them be easily reduced into one flexible Mass by the Force of Fire, cohering as strongly together as at first before they were divided. But yet the Fire feems to have made no Alteration in the Gold; it only feems to have removed the Matter which interposed betwixt its fmall Particles, in fuch a manner as to Aa3 bring

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bring their Surfaces into close Contact; and therefore when the Force of the Fire is abated, the Particles cohere together by their mutual Powers of Attraction, increased by their closer Contact. For it is this immediate Contact of Parts, which is the true Cause of their Cohesion, as we are assured from numerous Experiments. When a glass Lens is polished for optical Uses, in which Artifice I formerly amused and delighted myself, we observe that the Glass moves freely in the Plate so long as there is the least Quantity of Emery, Oil, Wax, or the Moisture of one's Breath interposed betwixt the Glass and the Polisher. The Polisher grows hot from the swift turning round of the Glass, and if the convex Surface of the Glass touches the Concavity of the Plate and Polisher, they will cohere together in a Moment so as to relist Separation. But this Inconvenience never happens, unless the Machine is become very hot, and the intervening Matter is quite expelled from betwixt the Glass and the polishing Plate; but when the Cohesion betwixt the Glass and the Polisher is separated, they repel each other, nor will they ever cohere again, unless so great a Heat and Force of Fire was applied, as is capable of expelling the foreign Matter which was interposed betwixt them.

We faid before that the Glass most strongly adheres to the Polisher, when the Figure of the polishing Lens very exactly fitted the Cavity and Shape of the Plate, so as to fill it entirely and come immediately into close Contact, whereupon they immediately rest and become immoveable. From hence we conclude, that there is no Difference in the constituent Particles of a Solid and Fluid; but that all the elementary or constituent Particles of a Fluid will compose a Solid, so soon as they touch

each

each other immediately in plain Surfaces, without the Intervention of any other Matter. Thus we fee that the component Particles which we call Fluids, while they are continually moving through the Vessels of our Bodies, do nevertheless become solid, when by the Power of Attraction they adhere to the Sides of the Vessels. A little Ball of Wax does not adhere to the Finger, because it touches but in a small Point, whereas if it be pressed flat by the Finger, the Surface being extended will cause it to adhere very firmly.

§. 444. Therefore such Particles as are now in a sluid State will compose or form part of a Solid, so soon as the Power of Cobesion! shall cause them to combine with the other solid Particles, by whatever Cause that Power of Cohesion is produced or increased.

The Particles of the Blood compose a Fluid in the Vessels, because their Points of Contact are continually varied; and therefore the Blood must of Necessity be sluid, so long as the Arteries continue to act upon it; but if the same Blood stagnates and is urged against the Sides of the containing Vessel, without the Intervention of any aqueous or different Particles, a Solid will then be certainly formed out of the Fluid.

That Attraction is one Cause, if not the chief or only Cause, appears probable, inasmuch as a calcined Bone which retains its Figure being applied to the Tongue, adheres very powerfully to the Skin, so that it cannot be pulled off from the Tongue without great Pain and a Laceration of the

Part.

§. 445. And this Cohesion of the Parts is best produced in a Fibre already formed 1, if there are hollow Spaces 2 lest betwixt the solid Particles capable of receiving more Matter in the Place of those Particles which have been wasted; and at the same time if there are Particles in the Fluid corresponding in Size, Figure, and Nature 3 to those Vacuities; to which add a sufficient Power or Vis Vitæ 4 capable of adapting or thrusting in those Particles into their corresponding Vacuities.

We do not pretend to determine the Manner in which the Fibre is first formed of its constituent Particles, we only explain how the Fibre already formed, increases or grows from the Aliments as the Animal advances in Age; or how it is regemerated and repaired by Matter, supplying the Confumption or waste which is made of all the Parts by the continual Attrition and Motion of them. We suppose the Fibre to be present and already made, without enquiring into its first Principles, which are too obscure to come under our Apprehension. The Person who enquires after the Manner in which the first Fibres were formed in the Animal, falls into the old Difficulty concerning the Egg and the Hen, or the Seed and the Tree, concerning the Priority or Pre-existence of which there have been many Disputes.

Suppose one of the smallest Fibres, composed of two solid elementary Particles, applied to each other by their Ends; for we cannot here suppose any Parts to be joined laterally in the most simple Fibre. Let this Fibre be again extended by the Vis Vitæ which distends the Vessels, upon the

Convexity

Convexity of which the Fibre is placed in fuch a manner, as to cause the contiguous Particles to recede from each other to a confiderable Distance, but yet not so as entirely to destroy their Cohesion; there will in that Case be formed a void Space betwixt the Particles by the Elongation of the Fibre; in which Space there will be a less Resistance, so that any Glew or other Matter may eafily fill up the Interval which was made by the Attrition and Power of the Actions of Life: while the Particles which were abraded, are washed out of the last formed Intervals, are evacuated by infenfible Perspiration, and the other Emunctories (§. 432.) But even the very fame Humour which abraded the elementary Particles is full of others of the same Nature, of which the solid Fibres may be composed and renewed. These Particles paffing along the fmooth Surface of a fmall Veffel, will nevertheless infinuate themselves into any Vacuities agreeable to their Size and Figure, into which they will be forced by that Impulse of the Humours, which distends the Vessels in a Direction perpendicular to their Axes, while the Impetus of the following Humours will more compact and polish the newly supplied Parts, so as to reduce them to a Level with the Surface of the Veffel, abrading the superfluous Parts, and supplying or filling up all the Intervals made betwixt the elementary or conftituent Particles. Hence it is, that a true Increase of the Body very seldom takes place in Adults. For if a Fibre is fo strong, as to be neither furnished with Vacuities by Elongation, nor by an Abrasion of its Parts, there will be no Matter added, but its Surface will be on all Sides fmooth; but if any Vacuities are formed by the Vis Vitæ, as many Particles will cohere and adapt themselves as there are Particles abraded.

And in general, Nutrition never takes place, but where there are some Parts abraded or worn off.

The Particles ought to be flexible and tenacious. The red Globules are perfectly spherical; but when they arrive at the smallest Extremities. or Anastomoses of the sanguiferous Arteries, they assume an oval Figure, as Lewenboec has observed: in order to which it is necessary for them to be flexible, and not endowed with the adamantine Hardness. The serous Globules also retain the fame Sphericity and Flexibility, but are fix times less than the former; and have so much a greater Degree of Cohesion, that they run into long Threads or Chains, which, together, form a folid Cake of the whole Mass, when extravasated. Yet neither does the Blood nor the Serum nourish. for if fo, only the ferous and fanguiferous Veffels would be supported: but that Liquor, which is the immediate Matter of Nutrition, must be so exceeding fine as to be capable of pervading the very smallest Vessels of all in the Body (§. 451). Since, therefore, the Particles of all the nutritious Humours are flexible, and derive their Sphericity from the continual Rotation among other fimilar Spherules, they will be also capable of altering their Figure by the vital Pressure or Actions of the Veffels; which is a Property never observed, either in the Particles of a Medicine, or of a Poison, which are too rigid and inflexible to yield to the Action of the vital Powers.

\* After a small Globule has entered into a Vacuity, a further Power is necessary, in order to break off so much as projects beyond the Surface, and to compact and polish the Remainder.

§. 446. The true Nutrition of the Solids must be therefore performed in the *smallest* in Vessels,

Vessels 2, of an Assemblage of which the larger Vessels are composed; that is, in the Nerves, or in the most minute Vessels, much like unto the Nerves themselves (§. 302, 440.)

All Parts of the human Body are composed of Vessels before they become callous; but after they have once arrived to that rigid and inflexible State. they are no longer nourished, as they do not admit of any Parts to be abraded: for Nutrition in the full grown Animal is no more than the Reftitution of those Parts of the Vessels, which have been abraded by the Motion and Attrition of the Humours flowing through them; and this can take place only in Parts that are vascular. But the Veffels have a twofold Surface, one external. to which pass the exhaling Vapours which are difcharged into the larger and fmaller Cavities of Hippocrates; the other internal, transmitting the contained Fluid: the former of these receives but little Alteration, as it only exhales fo much perspirable Moisture as is necessary to prevent the Concretion of its Fibres; whereas the latter fuffers a confiderable Pressure and Attrition from the Impulse of the Liquor flowing through the Cavity of the Vessel. Hence therefore it appears, that Nutrition must be performed within the Surfaces of the smallest Vessels.

The first and common Root of all the other Vessels in the Body is the Aorta; and the ultimate and smallest Vessels which are from thence continued so as to come within the Reach of our Senses, are the perspiring Vessels of Sanctorius. But whatever the last or smallest Series of Vessels may be, it is certain, that they admit of none less than themselves; and that therefore they must be composed of mere simple Fibres and elementary Particles,

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and not be made up of other smaller Vessels. which would be contrary to their Definition. But to prevent their Fibres from growing together, it was necessary for them to transmit a kind of Moifture very fubtle to separate and divide them; for if this Moisture was not extremely subtle, it could not pervade the smallest Vessels. It is therefore this most thin Liquor which nourishes the smallest Vesfels (agreeable to §. 445.); and the true or immediate Matter of Nutrition is fo fubtle a Liquor. that it is capable of pervading the most minute Vessels in the Body. But the last Series of Vessels but one are composed by an Intertexture of the other smallest Vessels, which themselves are only made up of Fibres, in the same Manner as if the Intertexture of small capillary glass Tubes was convoluted into another Vessel (§. 445.): and the Nutrition of this penultimate Series of Veffels is carried on by the other smallest Series of which they are composed. Therefore this penultimate Series is nourished as well internally by the Fluid which it conveys, as externally by the more fubtle Fluid of its smallest component Vessels. Again, the antepenultimate Vessels are composed of those last mentioned; so that Nutrition will be carried on in these, as well in the ultimate as in the penultimate, and in the Cavities of these antepenultimate Vessels themselves: and thus are the larger Vessels composed and supported by the smaller ones, 'till we come to the very largest of them all, namely, the Aorta. The Aorta is therefore nourished by all the several Classes of Liquors and smaller Vessels in its Composition, derived from the Blood in its own proper Cavity; and for this Reason that Vessel distributes all the Kinds of Liquors in the Body from the Heart, that the continual waste might be repaired which arises from

so great a Celerity and Attrition of the circulating Blood.

§. 447. Since therefore Nutrition cannot be performed but by a Liquor capable of pervading these smallest Vessels, I believe you will readily allow that the immediate Matter of Nutrition must be the most subtle i nervous Juice, or some other much of the same Nature.

' So subtle as to be capable of exhaling through the Pores of an Egg-shell. It is demonstrated, that the Body of the Chick arises not barely from the Albumen of the Egg, but also from the Addition' of a more subtle Matter; for Bellini proves, that the Egg is heavier when the Chick is near being hatched than it was at its first Incubation, and again, that the Chick itself breaking out of the Shell is much heavier than the Albumen and Yolk together. This additional Weight must therefore have been derived from the Air, or from some of the exhaling Vapours of the Hen, during the time of her Incubation; and confequently it must have been so subtle as to pass through the stony Shell, which is perforated with many small Pores at the obtuse End of the Egg, passing afterwards through the common tough Membrane, and through the feveral concentric Lamellæ of the Albumen; at last through the two including Membranes of the Colliquamentum, which ferve for the Chorion and Amnios, and at last passes with the other Humours under the Form of a Jelly, through the Mouth of the Chick itself into the Stomach. Nor does the Egg absorb only that Matter which gives it the additional Weight during the Time of Incubation; but it has inhaling Vessels, which absorb a much larger Quantity of Vapours, which are probably exhaled again. For those Liquors which are less gross than Water, escape our Senses. In a chemical Distillation of the White of an Egg, there is always some Part lost or exhaled, though the Vessels be ever so exactly closed, which Loss amounts to near a tenth Part of the whole; and must have been therefore of so subtle a Nature, as to escape through the Luting and Junctures of the Vessels.

- §. 448. Does it not therefore seem credible, that Nutrition is one of the ultimate 1 and most perfect Actions of Nature? And that in order to the due Performance of this, all 2 the several other preparatory Actions of the Body are required to be carried on in a healthy and regular manner.
- The Albumen of the Egg does not itself nourish, nor is it immediately converted into the solid and fluid Parts of the Chick before it has passed through all the succeeding Degrees of Attenuation (§. 442.), pervading the several concentric Lamellæ, which are infinite in Number, and have each their respective Albumen, the last of them being the Sacculus of the Colliquamentum reduced to the greatest Degree of Tenuity. We therefore need not wonder, that so long an Elaboration and Attenuation of this Humour is necessary, in order to render it capable of pervading the most minute Vessels, since the Humour appears in its crude State to be so thick and viscid.
- <sup>2</sup> Namely, that of passing through the Heart, sanguiserous, serous, and other smaller Vessels. Among all the Humours of our Bodies, the red Blood suffers the least Action of any, as it only circulates through the sanguiserous Series of Vessels;

whereas

whereas the Serum undergoes the Action of two Series of Vessels, namely, that of the sanguiferous and of their own proper serous Vessels, the Diameter of which is equal to the Semidiameter of a fanguiferous Vessel. But the nervous Juice has undergone the Action of all the Series of Vessels; and therefore fuch a Juice is the most proper to supply the Matter of Nutrition, as having fuffer'd more from the Power or Action of the Parts than any other Liquor. Nutrition must be therefore performed in the smallest Vessels, which are only capable of receiving the nervous Juice, or a Liquor equally fubtle. From hence also Nutrition appears to be the ultimate Action of all the Parts and Humours in the Body, for the due Performance of which all the others ought to be rightly disposed: and agreeable to this we observe in Practice, that when the primary Actions are defective, this ultimate one of Nutrition is impaired or abolished; as for Instance, when the Lungs are decayed.

- §. 449. The Chyle therefore may fill the larger 1 Vessels, but cannot immediately nou-rish 2 or repair the solid Parts of the Body.
- As the Aorta fuffers the greatest Violence and Destruction of its Parts, so it is also repaired by more Powers than any other Vessel. But the Vessels are never observed to have large Fragments abraded, but only small Scales, which are capable of passing out of the Body with the Urine and perspirable Matter. But the larger Vessels have equally the same Juices with the smaller Branches; that is, the Aorta, as well as the smallest sanguiserous Vessels, have each their respective Blood and more subtle Juices, that every Particle which is abraded may be supplied with others of corresponding Dimensions.

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Lewenboec informs us, that he finds Globules in the Chyle not much less than those of the Blood, but of a more rare or lax Texture, as not being compacted into so dense a Mass (§. 87, 127.): the Chyle therefore cannot itself nourish the Parts, since its Globules are too large to enter the smallest Vessels, nor does it ever enter into any other than the lacteal Veins, and the lactiferous Ducts of the Breast; for it is never sound either in the serous or lymphatic Vessels.

§. 450. But when the same Chyle has been attenuated by the Force of Respiration in the Lungs, where it is intimately mixed, ground together and changed, it becomes fit to enter and pass through some smaller Vessels, and is indeed advanced nearer towards the Matter of Nutrition, from which it is however as yet considerably remote.

There is a considerable Alteration or Change thus made by which it differs from the Chyle; for it is not so acescent, not does it congeal into a Curd-like Substance. But though the alimentary Juice is thus render'd somewhat more suid than the Chyle, one may readily perceive that it cannot as yet be substelled enough to be received into the most minute Vessels of the Brain; for if Milk could be in this manner so easily attenuated, Nature would never have been at the Expence or Labour of causing the Albumen in the Egg to pass through such an infinite Number of Degrees of Attenuation in its Course through the concentrical Lamellæ, but that Humour would have been immediately sent in a direct Course into the Vessels of the Chick.

§. 451. But in time, by the repeated 1 Action of the Lungs, Viscera and Vessels, the Chyle becomes a mild, tenacious and nutritious Serum, having little or no Taste or Smell, and congealing with the Heat of Fire, or the Addition of Alcohol Vini, very much resembling 2 the White of an Egg: fo that it then appears to be fuch a Fluid, as contains all 3 the Qualities or Conditions which we find to be necesfary by Experience in that Humour, from whence we know all the folid Parts of the Animal are derived 4 by Incubation only. Thus therefore the Matter is brought a Degree nearer, though it is not as yet 5 quite fitted for Nutrition; much less is red Blood fit for this Office. nor does either that or the Serum ever enter into the smallest Vessels.

The Chyle being received into the lacteal Veffels, passes from them into the thoracic Duct and fubclavian Vein, from whence it passes into the right Ventricle of the Heart and pulmonary Artery; but as yet it has passed through none but large Vessels, having met with no Difficulty from the Smallness of their Diameters. But, in the next place, it is urged through the minute Anastomoses, of the pulmonary Artery and Vein, and by the Aorta it goes through all the Muscles and Viscera together with the Blood, circulating throughout the whole Body under the Denomination of Milk. This Chyle or milky Juice of the Aliment is not converted into Serum within three Hours after a Meal; but if Blood be drawn about that time from a Vein, this Liquor appears floating of a Bb

white Colour upon the Surface. Although the Chyle appears then to have undergone the Action of the Arteries and Lungs, yet it has not been fufficiently attenuated and changed to form the Matter of Nutrition. But about twelve Hours after a Meal, the lacteal Juice of the Chyle puts off its white Colour, and becomes a pellucid Serum: nor does it evaporate by Heat, but congeals into a scissile Mass like Leather. .

2 But there is this Difference, that the Albumen is contained in concentric Sacculi, while the Serum of the Blood flows freely through the fanguiferous Vessels in a more fluid State; to which add, that the Serum receives fomething from the Blood itself. whereas in other respects both the Serum and Albumen are very much like. Both of them harden by the Addition of Alcohol Vini (§. 226.); and in Distillation there is no Difference perceived betwixt the Serum of the Blood and the White of an Egg; both of them afford Phosphorus by the last Degree of Fire, and both of them receive the same Changes by Putrefaction; but even the End and Uses of both are the same. The Females of all Animals receive truly the Semen masculinum into the Serum of their Blood. All Sorts of Animals. whether Fish, Fowl, Quadruped or Infect, are generated from Eggs, without excepting any, as far as we have been yet able to discover. In these Eggs the Fœtus's of all Animals are nourified and brought up to that State of Perfection, in which we meet with them at their first Appearance in the World; whether the Egg was incubated either within or without the Animal, or brought forward by a determinate Degree of Heat. Almost all Birds fit upon their Eggs, and within the Space of twenty-four Days they hatch their Young, and let them out of the Shells. All Infects do not fit upon upon their Eggs, but they are hatched by Warmth, as in the Species of the Eruca. But where ever these Eggs are laid, they are always surnished with their Albumen, which is in effect a true Serum deposited from the serous Vessels of the Mother within the Egg, the Cavity of which it fills. But in Birds there is a stony Crust formed round this Serum, that the Eggs might be preserved safe in the Cold for the Space of three Months without injuring the Fœtus, which may be excluded from the Egg, notwithstanding it has been kept so long, provided it is set under the Hen.

<sup>3</sup> This is the true plastic Spirit or Moisture of the ancient Philosophers, out of which all the solid Parts of the human Body are formed as out of a

Paste.

4 The Albumen of the Egg within the Space of twenty-one Days is, by a determinate Heat, changed into the Substance of a Chick. And the like Albumen or Serum is fo prepared and attenuated by Heat, and the repeated Action of the Vessels of the human Body, that it passes through several Series of smaller Vessels in the same manner as the Albumen of the Egg is percolated through the concentric Sacculi. There is therefore no Obstacle against the Serum being the Matter of Nutrition. provided it passes through the several Degrees of Attenuation, like the White of the Egg before it forms the folid Parts; for from fimilar Caufes we may expect fimilar Effects in Subjects of the fame Nature. But when the viscid Serum of the Blood is not formed or generated from the Chyle, as in confumptive or phthifical Patients, in that Cafe the whole Business of Nutrition is abolished. For there are many Vessels in the Body, which do not admit the yellow Serum of the Blood to enter into them in a natural State; as we observe in the Bb 2 uriniferous

uriniferous Ducts, the pellucid Lymphatics, the lactiferous Ducts of the Breafts, &c. in which we never find any Serum capable of hardening with Heat, or Alcohol of Wine: but the Humours of those Ducts are groffer than the Serum, and there are many others not much more fluid. When the Arm of a healthy Person is placed in a clean glass Vessel in the Summer-time, the Vapours exhaling from the Skin will be condensed into Drops adhering to the Sides of the Glass (§. 426.), and will again evaporate from the Glass without leaving any Refiduum or groß Matter behind; and therefore it contains nothing of the Nature of Serum or Oil, for either of these leave a Spot behind them continually, and the Serum congeals into a hard Jelly by the Heat of boiling Water without evaporating.

The Serum of the Blood has not indeed acquired all the Properties of the nutritious Humour; but it must first undergo a very high Attenuation, before it can become sufficiently subtle to perform the Office of Nutrition. Thus also the Albumen of the Egg does not immediately nourish, but that Humour which is prepared from it, and sent into the Sacculus of the Colliquamentum, being much

finer than the Albumen unprepared.

§. 452. But as the Heat 1 of Incubation, fo the Actions of the Viscera and Vessels, as-fisted by the same Heat arising from the vital Powers, introduce divers Changes continually in the healthy circulating Serum of the Blood, till at length some Part of it becomes so subtle 2 a Humour as is required for the Business of Nutrition, in order to repair immediately that which is wasted; and it is this last most

most subtle Humour, prepared from the Serum of the Blood, which at length becomes the true and immediate Matter of Nutrition.

In the Metropolitan City of Egypt, at this Day termed Grand Cairo, Eggs are hatched in Ovens by the Application of a certain Degree of Heat; but if that Degree of Heat is too much exceeded, the Eggs come to nothing. So also it is with us; for our Bodies are not nourished when the Blood

is kept in too great a Heat.

2 From the gross Chyle is formed another which is more fubtle, in the Form of a Liquor which is converted into Milk, which Milk is converted into Serum, and that Serum into Blood; but the Blood itself is again resolved into Serum and that Serum into Lymph, which Lymph is attenuated into feveral Orders of Liquors still much more fubtle. In the same manner is the Albumen of the Egg attenuated and fuccessively propelled through the concentric Sacculi, 'till it at length' enters the Colliquamentum in the Form of a most fubtle Liquor through the Chorion and Amnios. In both these Cases the thing is the same, though we are not capable of enumerating the feveral Degrees of Tenuity in the Particles either of the Albumen or Serum. But how fubtle a Liquor may be prepared from the Aliments we are taught, by the Instance of the Alchemist; for the good old Man had read, From thee O King is drawn the Matter, my Breath is my Life. Hereupon he proclaims himself victorious, and taking a large chemical Veffel breathes into it for fo many Days and Nights until a large Quantity of Liquor was collected. But still it remained for him to fix this volatile Mercury of Life, but he could never find himself able to restrain the Fugitive from evapo-B b 3

rating immediately upon feeling the Heat; to do this he tortures his Mind and Body to no Purpose, 'till being overpowered with Labour and Fatigue, he finds himself to have wrought the great nothing. These Men have certainly a happy Stock of Foolishness, and are fit to furnish out Experiments to better Philosophers who never fatigue themselves with so much Labour to so little Purpose. Certain it is that from such gross Food and fuch thick Chyle and Blood, are formed Juices in themselves so extremely volatile, that they fly off into the Air spontaneously, in the same Manner as the Albumen of the Egg which has not been fœcundated is so highly attenuated by the Heat of Incubation, that after Putrefaction it exhales through the Shell. Even a new laid Egg continually exposed to the warm Air becomes lighter every Hour, and the Cavity at the obtuse End by degrees enlarges and occupies the whole Egg, 'till at length all the Humours exhale through the including Shell and Membranes, leaving nothing behind but a small Quantity of Earth. If we substitute an Egg to a chemical Analysis, all the Parts which are oily and watery will arise by the Heat of the Fire, leaving only a black Sediment remaining, which after Calcination affords a fmall Quantity of a white Earth.

§. 453. But how simple, insipid, and inodorous this nutritious Humour is, we are taught by Fire, Putrefaction, and Chemistry; for there is nothing left after these Processes more than a very light 2 and simple Earth 3.

The more any one of our Humours is elaborated and subtilized, the nearer it approaches to

the Nature of Water; but yet is there a confiderable Difference betwixt them and real Water; for that last dissolves instead of nourishing the Parts. nor can a Man support his Life with mere Water, but he will foon be deftroyed. There are Inftances of Captives which have fasted for the Space of twenty Days when they have been supplied with Water, whereas they could not have subsisted fo long as nine Days without Water; nor yet does Water nourish. But the nutritious Fluid differs from Water inafmuch as it is generated from the Serum of the Blood, which alone has the Property of hardening with Heat among all the Humours of the Body: for the Chyle, Saliva, Semen and aqueous Humour of the Eye do not thicken like the Serum of the Blood (§. 246.); but this Property of coagulating is a Characteristic of the nutritious Humours. After I had distilled the White of an Egg, there remained in the Bottom of the Vessel almost one tenth Part of the Consistence of Horn, while nineteen Parts were drawn off in the Form of Water, but somewhat different from common Water, fince it would kill Quickfilver, which Rain-water will not; for which purpose it was therefore esteemed a Secret by Helmont and There is therefore a certain plastic and cohesive Property in the Serum of the Blood, and in the White of an Egg, which is not found in Water. Not that I would have it supposed that the Serum itself nourishes, but that from the Serum attenuated by the vital Powers is formed a very fubtle aqueous Liquor, in the same manner as the Chyle is by the vital Powers converted into Serum, which hardens with Heat; and that the Serum at length nourishes, after it has been so highly attenuated as to become perspirable. And this fecond Kind of Attenuation which the Serum receives Bb 4

ceives renders it unalterable; for the Serum cannot be hardened after it has been once attenuated in this manner; nor can the Albumen of the Egg be indurated by Alcohol Vini after it is become semi-

putrid by Incubation.

Which are altogether volatile. An old Man of eighty Years of Age has perhaps changed his Bones a hundred times, receiving new Nails and Flesh, while the old Bones, Flesh, Nails, &c. have been fo wore away and evacuated from the Body infenfibly, fo as to leave nothing fixed; and this not without Surprize to those who are skilled in Chemistry, who see that by a moderate Heat those Parts are volatilized, which remain fixed even in the most intense Fire. Hence Helmont rightly observes, that unless the ingested Aliments are attenuated and volatilized into a fubtle Dew. the Person will in a little time be reduced to a Mass of Earth. For the Aliments by which we are nourished, are replenished with earthy Matter, with which we should be in a little time stuffed up, if it was not to be volatilized and infenfibly discharged. These solid earthy Particles or Elements being reduced to a great Degree of Subtlety, are alone capable of pervading the smallest Vessels, and of affording the immediate Matter of Nutrition.

The folid Parts of the human Body are made up of mere Earth, which is neither resolvable nor mutable in Water, Fire, or Air; but Water renders these solid Parts more compact: Earth is the Basis, Water the connecting Glue, and from both is formed the solid Fibres of the human Body.

§. 454. But we find that this ultimate Matter (§. 452.) can be only prepared by passing through through all the Degrees of Attenuation (§. 449 to 453.)

- §. 455. But the same nutritious Humour may become acrimonious 1 by a too swift and frequent Circulation, or by being too long retained, whence its Fluidity may be destroyed, and its Substance thickened, its oily Parts being drawn off or exhausted, and the Salts sharpened, from whence it becomes unfit for this Purpose of Nutrition and Secretion.
- All Animals both Male and Female are nourished with Milk; and even in the Breasts of new born Infants of both Sexes, as well as in grown People, there is Plenty of Milk to be found. But this Humour does by continual Heat and Motion become acrimonious, notwithstanding it is at first mild, or fweet, and anodyne: for from Milk is generated Serum, and Serum merely by too long a Circulation becomes acrid and fœtid, evacuating itself by Urine, which alone by Rest and Heat affords the most acrimonious Salts. By mere fasting alone all the Humours become acrimonious, as Tschirnbausen has rightly observed (§. 66.); and there are many Instances in which the Saliva has been acrid enough to corrode the Gums, and the Urine the Bladder; for while the more fubtle Parts are exhaled, the oily Parts are wasted or confumed, and the Salts rendered more acrid.
- §. 456. From hence therefore we see the Necessity there is for the Blood and Humours to be replenished with new Chyle 1, from the repeated Ingestion of solid and fluid Aliments, in order to carry on the Business of Nutrition.

The

The Necessity for Food to be continually taken into the Body, is not in order to keep the Vessels full; for in the dead Bodies of the human Species, as well as in those of Brutes, the Vessels are found full of Blood, and contain ten times as many Juices as there are found in the Body of a tabid Person. But in a Man who has suffered Hunger for a long time, all the Humours are attenuated and rendered more acrimonious by their continual Heat and Motion, by which they incline to Putrefaction, and occasion Thirst, Fevers, Madness, and at length Death itself; and in the dead Bodies of fuch, the Brain appears flaccid, and in a manner destroyed. Namely, because the fresh Chyle is wanting, which by its gentle acescent Quality might temperate the putrefactive Nature of the Humours; and in all Animals, without excepting the most fierce, the Chyle is the mildest Humour of any in the Body, as it ought to be to temperate the acrid Humours, dilute and correct them as they are corrupted and wasted by the continual Actions of Life, more especially as the Animal is more fierce and prone to Wrath. There is also the same Necessity for Drink to wash out the putrid Particles from the Blood and Humours. which if retained in the Habit would injure or deftroy the tender Fabric of the Brain and Cerebellum.

§. 457. But for the Manner how and the Causes from whence Nutrition is performed, we may sufficiently understand these from what follows.

§. 458. The Humour being propelled strait forwards through a full, conical or cylindrical

cal Vessel 2, either elastic or rigid, passes from a larger Capacity to a less; and from the Resistances opposed to its Motion, it will endeavour to extend or dilate the Sides of the Vessel according to its longitudinal 3 Axis. And this happens throughout the whole Body except perhaps, in the Veins and cavernous Receptacles 4.

All the Vessels of the human Body are flexible; and even the Bones themselves were at first mere Membranes pervaded with flexible Veins. And besides this all the Vessels are full even unto their last Extremities, as we are convinced by the

Microscope (§. 213).

2 It matters not what Figure the Veffel be of. provided it be full and the Liquor flows through it with a certain Velocity; for then the Liquor with which the Vessel is already filled, will resist the Entrance of the next which follows, which consequently cannot pass into the Tube unless it removes or thrusts forward the preceeding Liquor from its Place. That Liquor therefore which is projected from the Heart into a full Veffel fuffers the Action of a Press, betwixt the Force of the Heart urging behind, and the refifting Blood before, which it is obliged to move forward with the Refistance from the conical Figure of the Ar-Therefore the whole Force which the Blood receives from the Heart will be returned upon the Sides of the Veffel, as Herman demonstrates. But as much as the Sides of the Veffel are diftended with the Blood, so far are they removed from the internal Cavity; fo that when the Blood preffes upon the Sides of the Artery and is again repelled by the fame, it exerts its Force according to

the Length of the Vessel, endeavouring to go forwards, and by that means to elongate the Vessel itself.

For fince the Vessel is conical, all the Particles of the Humours which are propelled by the Force of the Heart in Lines parallel to the Axis of the Artery, will strike directly upon its converging Sides, and by removing evrey Point of the stexible Vessel, they will endeavour to elongate the same, unless the Canal resists with an infinite Force. But there are no such infinitely resisting Vessels sound in the healthy human Body, or if there were such, the Circulation of the Humours would in them be certainly stopped. Since therefore the Vessels give way to the Impetus of the Humours, they must of necessity be elongated.

\* Namely, in the Veins the Humours flow from a narrower to a larger Part of the Vessel continually into larger Receptacles, and therefore in fuch Veffels the Sides are pressed only by the Weight of the Humours: nor do they endeavour to elongate the Vessel, since they find a ready Passage free from Resistance towards the Heart, which being contracted and emptied forms a Vacuity for the Reception of the succeeding Blood, which therefore runs freely from the Veins into the right Sinus, Auricle, and Ventricle. Hence therefore the two Ounces of Blood which are propelled from the Arteries into the Veins at every Systole, do not dilate the latter; and therefore there feems to be little or no Friction of the Blood in the Veins, though their Sides or Membranes fuffer some Attrition, as well from the Blood as from the Motion of their small component Arteries; and these being of the same Nature with all the other Arteries fuffer a like Attrition and Friction from the Blood.

§. 459. But by this Force, though very fmall, being continually repeated, the Veffels will be elongated gradually and infenfibly, and in their Elongation will be more and more extenuated, and that even in a short Space of Time 3.

This Force is not indeed fo exceeding small. fince it is equal with the Motion with which the Blood circulates, and by which no small Degree of Heat is produced in the Blood. But even suppofing this Force to be the least imaginable, it might nevertheless by its repeated Action produce the same Effect as the greatest Force acting in but one Moment of Time. For the Force which will elevate one Grain being repeated ten thousand times will raise more than a Pound Weight. When a Drop of Liquor falls upon the Surface of a polished Marble, it may produce no fenfible Effect or Abrasion in the Stone though repeated many thousand times; but by a continual Fall of Drops for many Years upon the Surface of fuch a Stone, there will be an Excavation formed equal to what an Iron Inftrument could produce with a greater Force in a shorter Space of Time; whence it is evident, that by a Repetition of small Strokes, the same Effect may be produced as by a greater Force in a shorter Space of Time. But the Power of Liquors in distending the Sides of the Vessels, and in elongating them according to their Axes, is exerted as often as our Arteries vibrate, namely, thirty-fix hundred times in an Hour, or eighty-fix thousand four hundred times in a Day. So that if the Force applied at one Instant to extend the Vessels is but small, by collecting together their Sums agreeable to the times, it will appear very confiderable.

2 All the Vessels are thickest and strongest towards the Heart, and become thinner as they recede farther from that Muscle, except only the Veins, which at their Sinus's in the Liver and Heart are covered with a muscular Membrane. The Aorta which is so extremely thick at the Heart, is so very fine and tender in its smallest Extremities which exhale the perspirable Matter of Sanctorius. that there is no great Difference betwixt the Cohefion of those Veffels and many of our Fluids. And the more any Artery is ramified into fmall Branches, the more thin and tender are the Sides and Membranes of those smallest Arteries. But the Impulse of the Blood propelled from the Heart into the Aorta, is continued from thence to the finallest Extremities of the Arteries, and even into the ultimate Pores, which are formed in part by the membranous Extremities of the Arteries, whether they terminate in Veins or excretory Ducts; for these last giving no Refistance, may be looked upon as Vacuities; and thus the Extremities of the Veffels will be extenuated in such a Manner, that approaching near to a Diffolution, they affume almost a fluid State. But all the Extremities of the Arteries are open, and may be therefore looked upon as Membranes cut short off; hence therefore the Vessel will be diftended and elongated most in these Extremities.

The Elongation feems to be manifestly the largest in the smallest Vessels. The Beard being cut off very speedily grows again; so that in an European Man who shaves once a Week, the Beard will acquire the same Length next Week as it had before, and thus there will be sifty two times as great a Length of the Beard cut off and renewed again within the Space of a Year. But this great Length of Hair which is shaved off from the Beard, much exceeds the Length which it would

acquire

acquire without shaving; for we know that European Men who follow the Custom of the Turks in Afia, have their Beards grow to their full Length within the Space of fix Months, beyond which they grow no longer; from whence it manifeftly follows, that the Hairs grow fafter by cutting or shaving, so that the Vessels meeting with less Resistance are more easily and speedily elongated by the impelled nutritious Matter. For there is not the least room to doubt that the Beard grows. or is thrust out by the Force of the Heart and Arteries, which move all the Humours, and extend all the Fibres. The Stag which every Year cafts off his Horns, has them again renewed annually, but always with one Branch more than before, fo that from the Number of Branches one may determine the Age of the Creature. In this Animal. after the Horn is cast off, there remains in its place a foft Tumor full of Blood, which is reekoned a Dainty at the Tables of Princes. These Tubercles turn into Horn by the time of the third Month, and in the ninth Month they are grown to their full Hardness; but all this Increase and Compactness of the Horn resulted only from the repeated Strokes of the Heart and Arteries. It is therefore evident enough with what a confiderable Force the Humours are propelled through the fmalleft Veffels of Animals.

§. 460. From hence therefore the ultimate Extremities of the Veffels, as being the thinnest and least compact, will be always 2 nearest to a State of Dissolution.

All the Vessels of the human Body are composed of elastic Fibres or Threads; but every elastic Thread is weaker in proportion as it is extended tended by a greater Force, and approaches nearer to a Diffolution: for the Strength or Resistance of any Chord by which it refifts Rupture, refides entirely in the mutual Attraction of its Parts. When a Chord is extended longitudinally, its conftituent Particles recede mutually from each other, but vet their Cohesion is continued as long as they remain in Contact; and upon removing the extending Force, the whole Chord contracts to its former Length: but if you continue the Extension longer, fo as entirely to remove the Contact of the Parts. the String will then fly in pieces towards opposite Directions. This Experiment may be tried in a fingle Hair, which will fustain an Ounce without breaking. Every fimple Fibre feems to be composed of folid elementary Particles, disposed in the same Order as Masons or Bricklayers build up the Walls of a House. Suppose then we have a Thread of fuch a Thickness, as to consist of four Rows of elementary Particles placed parallel to each other, fuch a Thread will have a powerful Cohesion: and let the same Thread be extended, till it is no thicker than two Rows of those Elements, the Cohesion will then be less; but if the Distraction is farther continued until the Thread is no thicker than the Diameter of one Chain of alimentary Particles, that Thread will then be the nearest it can to a State of Rupture, which immediately follows upon feparating the Cohesion of any two in the fingle Row of elementary Particles.

Hence it is, that when the Impulse of the Humours is increased against the Vessels in all Diseases, the Cuticle scales off; and this not all at once, or at any State or Season of the Year, as we see in Serpents, but almost continually or every Moment of Life, there are Scales cast off from the Cuticle. For the Scarf-Skin appears to be the

ultimate

ultimate Extremities of all the small Vessels of the Skin (§. 423.) Even by rubbing the Hands together, there are always more or less of these Scales abraded from the Cuticle, as there is likewise by washing the Hands: but these Scales are truly the Extremities of the cutaneous Vessels; and if you continue the Abrasion farther, it excites great Pain, and the Blood follows.

- §. 46 1. Thus therefore the ultimate Extremities of the Vessels are render'd so extremely thin and weak, that they differ but little from the Cohesion of the Fluids 1.
- There is nothing at all incredible in this Propolition. For the largest among the smallest Vesfels, namely the fanguiferous, appears to be fmaller than a Hair of the Head, where it joins with the incipient Vein, and the Microscope magnifies it to the Size of one's Finger. Therefore the largest among the smallest Vessels is thirty times less than a Hair of the human Head, which certainly is the least Proportion betwixt a Hair and the Finger, to the Bulk of which the fame Microscope magnifies the Hair. But the exhaling Vessels are still much fmaller by many thousands of times, the Number of which no one will pretend to determine. But these exhaling Vessels are not only seated in the Cuticle, but also in the Cavity of the Lungs, Thorax and Abdomen, as Hippocrates observes. But these ultimate exhaling Vessels are composed of more than one or a few, perhaps a thousand of the folid elementary Particles. It is therefore highly probable, that one elementary Particle confidered alone, is of equal Subtlety with the Particles of a Fluid; and when once abraded from its Veffel, it Cc

may fluctuate as easily after, as it did before when it was Part of the Chyle.

§. 462. Whilst therefore this Motion of the Humours (§. 458.) is perpetually continued forward by the Impulse (§. 458, to 462), these two Confequences must necessarily follow: namely, in the first place, that the ultimate Particles of these smallest Vessels being abraded, will again assume as it were the Form of a fluid Humour, in whatever Part of the Body they are feated; and in the next place, that the small Particles which compose the least Fibres will be so separated from their mutual Cohesions, as to leave intermediate Vacuities 1 betwixt those Parts where they before touched and cohered; and this likewise happens in every Part. Thus these two Consequences are continually produced in every Part of the Body at one and the same time, as long as Life continues; but this more especially in those Parts where the vital Powers are the strongest, and in those Bodies addicted to the most violent Actions and Exercises.

When one elementary Particle is abraded and evacuated out of the Body, another succeeds, and fills up the Space of the former; and this in a continual Succession, one Particle thrusting forward another, and filling up the void Space which the other occupied; and thus will there be a Succession of elementary Particles, from the Heart even to the Ends of the smallest Arteries, capable of repairing the internal Surfaces of the Vessels, and at the same time the Elements will be so changed and compact-

compacted, as to leave no Inequality in the Surfaces of the Vessels. But this is performed as well in the exhaling Arteries, as in those which open into the Veins; for the Veins may be in a manner considered as void Spaces, into which the Extremities of the Arteries are inserted.

§. 463. But the same Humour which both abrades and elongates (§. 462.) contains likewife a large Stock of fuch Particles as are of the same Nature with those abraded or destroyed; and these are conveyed and applied to those very Interstices by the Impulse of the fucceeding Humour, from whence arose the Destruction of the Parts; and the succeeding Matter being thus intercepted into the Vacuities, is by the Impulse of the same Humour fixed and formed so as to adhere equally firm like the former: for the Matter, the Preparation, and the Application thereof, with the moving Power in the nutritious Humour, always remains the same 1; whence follows an exact 2 Restitution of the lost Parts, so as to maintain the Solids in their former State, that is, to continually nourish and preserve them.

But the Humours of the Body remain equally unaltered, fince the Place of one Particle, which is abraded or exhaled, is supplied by another; so that the Elements both of the Solids and Fluids continue the same both in Number and Disposition, and only the individual Particles are altered. This perpetual Change of new Particles in the room of the old Elements continues as long as Life remains, and the vital Powers continue strong C c 2 enough

enough to convert the ingested Aliments into our own Nature; but when that Power ceases, the Restitution of what is lost or wasted by the Actions of Life sails, the Aliments retain their crude Nature, or they overpower Nature, as Hippocrates expresses it, and Death itself is near at hand.

For as much new Matter is applied in proportion to the Interstice or Vacuity, which is formed by the abraded Particles; while at the same time the rough or superfluous Extremities of the Particles which project beyond the Surface of the Vessel, are abraded and brought to a Level without leaving any Desiciency (§. 445), since the Vessels are in a natural and healthy State always full of healthy and nutritious Humours.

§. 464. But in this the wonderful Wisdom of the Architect is apparent, in contriving that the same Cause which inevitably destroys, should also at the same time, and by the same Means, repair the decaying Fabric of our Bodies; and that likewise from the same Cause the Supplies should be larger in proportion, as the Waste is greater; and that those Parts which are first decayed by the Actions of Life, should be always the first supplied and repaired with the nutritious Matter.

This Artifice is worthy to be admired by all Mortals, and is not to be matched in any other Machine whatfoever, namely, that the fame Force which abrades small Particles or Scales from the animal Solids so as to form Vacuities, should itself and at the same time repair the lost Substance with suitable Matter. Thus Life itself destroys our Bodies, as well as it repairs them; for Life is as well

the Cause of the Circulation in the Humours, as of the Destruction and Reparation of the Solids; the more violently we exercise the Body, the more do we wear off from it, and the greater are the Repairs made to the Solids.

§. 465. It is then evident, that the more minute or tender 1 those Vessels are, and the younger, as also the nearer they are to the moving Cause, so much the more easily may they be elongated, diftended, abraded, and again renewed.

So much more eafily are they elongated, abraded, and repaired. For fince the Particles are applied to the Vessels with a small Force, they are likewise abraded with but a small Force; nor can the refisting Forces in the Particles be greater than the renovating Powers. The smaller the Thread or Chord, the more easily is it extended; for a filk Line or Thread is much more extensible than a Rope, and a Chord which founds a high Note is more easily stretched than a thicker String which founds the Base. But the greatest Reason why Nutrition is the most copious in proportion while the Solids are young and more flexible, is for that in a Fœtus or Infant there are the greatest Number of Vessels, which diminish their Number in proportion as the Animal advances in Years: for that internal Force by which the larger Veffels are diftended, fo compresses and flattens their Membranes, that at length they become callous, and grow together. Thus we may eafily conceive that a Veffel, whose Membranes are composed of a hundred Fibres, will refift more than another whose Membranes are composed of a hundred small Vessels in-Cc 3

stead of simple Fibres. But the distending Cause is always the same, namely, the Force of the Heart; and therefore the stronger Vessels will be less extended than those which are more slexible; and hence it is, as Aristotle formerly observed, that the Heart has acquired its sull Magnitude by the twentieth Year of Age; whereas the rest of the Body grows even to the thirtieth Year of Age, so as to render the slender and comely Youth, a thick, square, and strong Man. For in the Heart the Vessels are the strongest, and from thence they become gradually weaker, as they are more remote, or recede farther from the Center of the vital Powers, the Heart itself.

- §. 466. Hence therefore our Bodies grow more i in proportion as they are nearer to the Birth.
- A human Egg weighs perhaps about fix or eight Grains in eight Days time after Impregnation; but all that time almost the whole Bulk of the Egg arises from the Membranes and Humours; whereas the fmall Animalcule which forms the Man is scarce one thousandth Part of the whole Egg; and yet from fo finall a Stamen within the Space of nine Months is formed an Infant weighing ten or a dozen Pounds, the Difference is as 1 to 9216000. But if the Body of an adult Person was to grow after that Rate, his Bulk would increase every Year Millions of Millions of times larger than before; fo that in a few Years he would exceed the Earth itself, which would not be capable of sustaining him; and he would equal the Stature of the Fish to which the Jews report the Messiah gave a whole Nation for a Meal. But even the first Year after the Birth the Infant grows not so fast as before, and

and still less the second Year than the first, and so on diminishing to the twenty-fifth Year, when the Increase is but a very few Ounces. But what feems very wonderful in the Growth of the Fœtus is, that it should be able to distend the Uterus from whence it receives its Juices: namely, the female Uterus appears so compact, that it can scarce be distended by Flatus; whereas if a small Ovum no larger than a Peppercorn comes into its Cavity, the Uterus will be fo extended thereby as to contain the Quantity of eighteen Pounds, to which Quantity the Ovum is enlarged. But yet there is nothing in the Ovum but what is received from the Uterus; and therefore it feems wonderful that the Uterus itself should be expanded by the very Humours which are derived from its own Body: but all this Force must arise from the little Heart of the Fœtus, however fmall, fince there is no other Cause of Extension in Animals but that of the Heart only.

§. 467. But while this Action (§. 458.) is carried on, the larger Vessels are more extended by their contained Liquors; but at the same time the smallest Vessels of which the larger are composed will be compressed, deprived of their Juices, and concreted together 1; from whence follows stronger Fibres 2, but at the Expence 3 or Loss of the smallest Vessels. The Strength of the Fibre refulting from the Cohesion of the constituent Elements or Particles, remains the same as if the Fibres were each separate: but the Power of a Membrane is increased by the Cohesion of the Fibres; fince the ultimate Particles or Elements in one Cc 4

of the smallest Membranes have twice the Contact and Cohesion which they have in a simple Fibre. Also the elementary Particles of a Fibre, formed by the Cohesion of two others, will be three times as strong as the Power of each of the two Fibres alone; and thus likewise in every simple or smallest Vessel: and the elementary Particles will cohere four times more strongly in a Membrane formed of the smallest Vessels compressed together into solid Fibres, &c.

the Subject, in the Beginning of our Practical

Aphorisms.

2 The Relistance of a simple Fibre against the Impulse of a diffending Fluid, may be considered as one Power arising only from the mutual Attraction of Cohesion betwixt the two Elements; but if to that Fibre another is applied laterally, there is a new Force produced, namely, that which refults from the mutual Attraction of the two Fibres in contact with each other's Surface; and if again a third Fibre be added, the Force will be increased to the Moment of three, fince the third Fibre attracts with the same Force as the second. If now these Fibres are formed together into a small Vesfel, their Power will be augmented to the Moment of four, by increasing the Cohesion of the Fibres, which being closed together by the Sides of each other compleat the Cylinder: and if feveral fuch Vessels are conjoined together, a fifth and a fixth Increase of the Power of Cohesion will arise, which will be still multiplied in proportion as the Membranes and Vessels are more compounded of other smaller Vessels and Membranes, by the contiguous Surfaces

Surfaces of which the Cohesion is increased. For it is evident, that the Cohesion of the elementary Particles, each of which do not separately cohere more powerfully, may nevertheless be increased to an immense Degree, only by increasing the Cohefion or Contacts of the Membranes and Veffels which they compose. If again the opposite Sides of a cylindrical Vessel cohere together, the Strength of that Vessel will be much increased only from augmenting the Contact of the plain Surfaces; and if one Vessel adheres to another, or several Vessels to others adjacent, the Strength of the Body will by that means be greatly augmented. Hence therefore it is evident, that merely by the Force of the vital Actions, the Strength may be immenfely increased, and the Vessels themselves diminished; for the Number of the small Vessels depends on their being pervaded by the Humours, and the Strength of them refults from increasing their Contacts.

The Heart is the Principle of all Motion in the animal Machine, which Motion is first received from thence by the Aorta; and the Coats of that Artery appear to be composed of innumerable small Vessels. Now when this Artery is extended by the Force of the Heart, the Vessels which compose its Membranes are compressed and concrete together; and in this Manner is the Number of the smaller Vessels in the human Body diminished continually, while the Strength of the larger Vessels is increased.

§. 468. So that the Parts which were formerly Vessels in us, do in Process of Time by inevitable Necessity, turn into mere hard Ligaments, as we are assured by Observation: for the Sutures of the Cranium, for Instance,

are quite obliterated in extreme old Age, which is an evident Sign of the Loss of a great Number of the small Vessels.

- Some of the largest Vessels in the Fœtus are doubtless the umbilical Artery and Vein, with the Canalis venosus hepaticus, and the Canalis arteriofus betwixt the pulmonary Artery and the Aorta: but yet these Vessels however large do nevertheless concrete and change into round impervious Ligaments soon after the Fœtus is delivered from its Mother.
- §. 469. Thus at length the Humours concreting, we have reason to believe 1, that the small Vessels coalesce or grow together with them from the same unavoidable Necessity.
- For the Blood of the umbilical Arteries does not return into the Course of the circulating Humours; but forming a polypous Concretion, it grows together with the Sides of the Vessel into one solid compact Chord.
- §. 470. Therefore by the Concurrence of these Causes (467, 468, 469.), the Strength, Thickness, Hardness, and Rigidity of the solid Parts is produced.
- Namely, the Concurrence of three Causes:

  1. The simple Combination of the elementary Particles into larger Fibres and Membranes; 2. The Expulsion of any foreign Fluid interposed betwixt the solid Parts; 3. A Compressure of the Vessels, so as to expel their contained Juices, and conjoin their Sides together.

§. 471. The great Number 1 therefore of the Vessels which are almost infinite in the Fœtus or Embryo, is gradually decreased, in proportion as Age advances.

This may perhaps feem a Paradox to fome notwithstanding it is most certainly true. For in the adult Person there are no new Vessels formed : and if we compare the Table of Arteries which Cowper has given us from a Fœtus with those of an adult Body, we shall find the same in both, and that there has been no Addition of any new Artery made in the Adult. Thus there are two coronary Arteries in the Fœtus, and there are but two in the Adult, though they are larger in the latter : fo are there two Carotids in the Fœtus, nor are there more in the Adult; and even the smaller Branches or Ramifications of the Arteries, which are visible to the Eye in an Adult, may be also traced by the Microscope in a Fœtus. But, on the other hand, we observe in the Adult, that five of the larger Trunks or Vessels, which we mentioned at §. 468, are destroyed and closed up. whereas they remain open in the Fœtus. But the fame thing is demonstrated to take place throughout the whole Body. Thus in the Palm of the Hand of a young Girl, there are an infinite Number of exhaling Veffels discharging a Vapour. which obscures a Looking-glass or a Piece of polished Gold, whenever they are touched by the Hand; but as the Country Girl grows up, and becomes inured to hard Labour, all those minute Vessels are destroyed and closed up into one continued Callus, which lines the internal Surface of the Hand; and in this manner the Blacksmiths of Amsterdam have their Hands lined with so thick a Callus.

Callus, that they can handle a red hot Iron without Pain. The Roman Cenfors were much in the right, when after examining the Hands of the Citizens, they deposed those as an efferminate Order of Men, whose Hands were found foft and smooth. Even the Wrinkles which appear in the Forehead of an old Person, demonstrate the Destruction of an infinite Number of the cutaneous small Vessels and the cellular Fabric, which filled out the Skin, Ruysch has demonstrated, that when the Vessels of a Fœtus are injected, an infinite Number of smalder Vessels appear in the Coats of the Arteries. which cannot be demonstrated in the Adult by any Injection, but are so entirely obliterated, that the Part of the Aorta which comes immediately from the Heart turns callous, and becomes at length cartilaginous, or even bony. All the Vertebræ of the Spine in a Fætus are each of them composed of a Body and Appendices; but the Bodies of the Vertebræ cohere to their Appendices neither by Muscles nor Ligaments, but merely by a peculiar Sort of Vessels. But from one Vertebræ to another, there are Fibres which pass in a perpendicular Course, and enter into the Substance of each Bone; but in old Age these flexible Fibres are all destroyed, and the Bodies of several Vertebræ concrete together into one Bone. The Skull of an Embryo is truly membranous, and composed of Vessels; all which Vessels are effaced, and turned into one folid continued Bone in old Age.

§. 472. For the same Reason also, on the other hand, Weakness goes off, and Strength is increased in the several Parts of the Body, as the Age advances.

Concerning

Concerning the Cohesion of the Fibres and their elementary Particles, we treated before (§. 467.) But when Fibres thus formed, are conjoined with others of the fame Make into one folid Body, the Power of their Cohesion will then be immensely greater. For if a Fibre is composed of fix Sides which adhere to others, its Cohefion will be fix times greater than before, and twelve times greater if it had twelve Sides. For Euclid has demonstrated what Figure can fill up any whole Space, namely, a square Hexagon, &c. But the Strength of the Fibres is estimated only from their Cohefions, fince the intermediate Spaces do not make any Refistance, and therefore cannot augment the Strength of a Fibre. The more numerous therefore the Fibres which cohere together, and the less the intervening Fluid which is interposed between them, so much more in proportion is the Strength of the Body increased.

§. 473. In Youth therefore the Quantity and Force of the Humours exceed beyond the Solids.

§. 474. But in old People 1 the Force and Quantity of the Solids prevail over the Fluids.

So long as a Fluid is interposed betwixt the Sides of the solid Fibres and Vessels, they do not cohere together. Thus two polished Pieces of Marble do not cohere, unless their Surfaces are covered with Oil or Wax, so as to exclude the intervening Air, and then they will sustain the Weight of six hundred Pounds without being pulled as a funder. But in old Age there are innumerable Vessels obliterated and turned callous, which

in the time of Youth and in the Fœtus were pervious and open; and therefore the Force or Strength of the Solids is gradually increased, till at length they resist any farther Dilatation. All the Increase therefore or Growth of the Body stops, so soon as the Force of the Heart can no longer extend the bony Fibres. The Head never increases after the Sutures are obliterated, and the Thighbone is no longer extended in Length, when the Force of the Heart is not sufficient to remove the elementary Particles from their mutual Contacts. Even the Growth of the Muscles themselves terminates, when the Bones are no longer extended; for they cannot be elongated, unless the Bones are also lengthened at the same time.

§. 475. From hence we may understand the Manner, Causes, and different Appearances of the Growth, full Stature, and Decrease of the Body, with that Death 2 of the Body, which results merely from old Age, and its Cause 3.

than the Refistance of the Vessels, so long are these latter extended, and the Body enlarges both in Length, Breadth, and Thickness; but when the Force or Resistance of the Vessels arising from the greater Firmness and Cohesion of the Fibres becomes more than equal to the dilating Power of the Heart, in that Case the solid Parts continually contract themselves, and the whole Body declines or falls away.

A healthy strong Person who is arrived to the fiftieth Year of Age, begins then to decline from the full Habit of Body; the Eyes begin to flatten, and the Person becomes short-sighted, nor is a mo-

derate Quantity of Light sufficient to render the Objects visible; the Hearing becomes difficult alfo, and the other Senses with the Faculties of the Mind become weak and dull. Some time after this the Body itself is inflected, the Head falls down betwixt the Shoulders, and the whole Body becomes at least two Inches shorter; for the Spine itself is shortened by several of the Vertebræ conjoining into one Bone, when the intervening Cartilages or Ligaments are compressed and reduced into a thin bony Lamella continuous with the Bodies of the Vertebræ themselves. By Degrees the Mind itself becomes feeble and childish, and at length that easy Extinction of Life which the Ancients to much wished for, follows from mere old Age, without those Agonies experienced by younger Persons, who are killed by Diseases before the Strength of the vital Organs has been exhaufted; infomuch that Death following from mere old Age. may be rather termed a Cessation of Life than a Destruction of it by Disease, since the Arteries become fo much indurated as perfectly to refift the Blood impelled from the Heart, In short, the smallest Vessels both in the Brain and Organs of Senfation are by degrees closed up, and then Death itself is near at hand, namely, when the Cerebellum fuffers the like Alteration. But the Veins only receive the least Alteration as being almost destitute of the contractile Force, and hence the Veins of old People are large and flaccid.

Vain therefore are the Boastings of the Chemists, who promise that they can prolong Life by their Elixir: for they conceive Life to be as it were a Flame, and if it was really so, one might reasonably expect some good Effect from Chemistry to answer that Purpose. Besides this they consound different Operations together, and

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imagine that to preserve a living Body is the same as to preserve a dead one, with Myrrh, Aloes, &c. If they were capable of continuing the vital Motions, we should readily grant that the rest might be very well expected from chemical Medicines; but, on the contrary, the Business is to open Vessels which are concreted together and become callous, which is not within the Power of Chemistry to effect.

§. 476. Whoever confiders this whole Hiftory or Account of Nutrition, and then compares therewith those Accidents which happen in the Body, he will clearly perceive all that we have here advanced to be truly the Case: for the whole Cuticle perpetually scales off throughout the whole Body, and is again renewed 1; the Hair 2, Nails 3, and Teeth 4 being continually shaved, cut or abraded from their proper Places, grow again; the loft Substance of the Vessels, Bones 5, and other Parts, are foon renewed from every Point; also the Sordes 6 or Matter collected from the Extremities of the Vessels throughout the whole Body either by fcraping or condenfing, being diluted in Water, and examined by the Microscope, appear to be composed both of the solid and fluid Parts of the Animal; and the fame Matter obtained from the folid Parts either by washing, rubbing, or scraping, has the same Appearance as before.

This is demonstrable various Ways. For the Callus is not merely the Cuticle thicker than usual, but an Assemblage of exhaling Vessels compressed

pressed and indurated into a dense and horn-like Substance, which is neither perspirable nor tubular, but confifting of Scales, an infinite Number of which are concreted into one Membrane. If a Smith, who has fuch a Callus in his Hand, for mollifies the fame by Maceration, that it all feparates from his Hand even to the foft Skin or Flesh. he will not by that Means recover a foft Hand. unless he abstains from his usual Labour: for if he returns again to work, another Callus will be formed, and his Hand will recover its former Hardness. The same thing is also demonstrated by abrading or removing those Spots, which being burned in the Cuticle are indelible by any Artifice whatever. If you diffolve Gold in Aqua regia, and touch any Part of the Body with the Solution, it stains a beautiful purple Spot in the Cuticle not to be removed by any Artifice; but in a few Days after, the Cuticle itself scales off, and a new Skin appears without any fuch Spot. Therefore the Extremities of the Vessels are continually protruded from within outwards all over the Body, and when abraded or destroyed, they are afterwards renewed again. But if the Cuticle is fo eafily renewed and altered, it may be asked, Why the fame thing does not happen to the Pleura and other Membranes, which are all perforated likewife with the exhaling Veffels? To which we anfwer, That the Epithelia or internal Cuticle, which lines the alimentary Passages and other Parts, has certainly small Vessels, and is likewise abraded and renewed; but then the Particles cast off are too fmall to come under the Observation of our Senses.

<sup>2</sup> If all the Hair of the Body was to be shaved off close to the Skin, it would grow again to its former Length within the Space of fix, seven, or eight Months. When an European Person goes

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into Afia, where he is obliged to follow the Eastern Customs, by which it is a scandalous Sight for a Man to appear without his Beard, upon fuffering it to grow, it acquires its full Length within the Time before-mentioned, beyond which it will grow no more. But in us who shave every two or three Days, there is certainly as much or a greater Length of Hair taken off within that Space of Time. If People who wear their own Hair would fave and weigh that which is combed off, they would find it to be equal, in a Year's Time, to that of the whole Head; and therefore the whole Head of Hair is renewed once in fix Months. I examined the Hair which was of a different Colour from the rest, and perceived that its Colour proceeded gradually from the Apex or Extremity towards the Middle, while its natural Colour was continued to the Root from thence. Our Hairs are therefore changed and extirpated in the fame manner as other Plants, though perhaps fomewhat more flowly; for in those Vegetables which are called Ever-greens, there are Branches and Leaves cast off, as we see in the Juniper, Tvy, &c. only they differ in this from the Generality of Trees or Shrubs, that they do not cast off all their Leaves at once, but by a few at a time, while others fucceed by degrees to supply the Place of those which are cast off. Hence therefore we may see that the Hairs cannot grow in a dead Body; which was a popular Error until it was refuted by Ruyleb, who by examining the Bodies of many Women after they had been buried thirty Years in their Tombs, could yet never observe that the Hair was grown in the leaft longer. For the Hairs are Continuations of the cutaneous Vessels themselves; nor can they be elongated or extended, but by the vital Powers which protrude the Parts from within out-I made wards.

3 I made a small purple Spot with a Solution of Gold in Aqua regia, upon the Lunula of the Nail of my Finger, and observed that it by degrees moved towards the Extremity, fo that by the third Month it was advanced far enough to be cut off. If a Person neglects to cut his Nails for a confiderable Time, they become strong and crooked. equal to the Length of the last Joints of the Fingers, as we fee in Brutes. Concerning the Reproduction of Horns we treated at §. 459; and indeed it is furprifing that a Stag, who has been castrated, should not in the same manner cast his Horns; which is a strong Argument that something returns again from the Semen into the Blood, capable of thrusting out or elongating the Fibres and Vessels, so as to cause the Horns to fall off, and grow up again.

There was a certain modern Anatomist who denied that the Teeth received any Growth or Nutrition; whereas it is certain that when any of the upper or lower Teeth have been extracted, those which remain opposite to the Vacancy grow out beyond the rest of the Teeth in a surprising Manner, because it does not continue to be wore away by grinding upon the other Teeth. It is therefore certain that every one even of the hardest Parts of the Body are surnished with very small Arteries not excepting the Teeth themselves, by which Vessels the nutritious Matter is continually supplied, and the Parts elongated, though by a gen-

tle, yet by a continual Force.

If any Bone which is of a considerable Length, and hollow on the Inside, be fractured in such a Manner that some Part of it falls out and leaves a void Space, (as I once observed no less than for the Space of two Inches in a young Man who broke the Tibia of his Leg) in that Case a mucilaginous or

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gelatinous

gelatinous Substance springs from every Point of the broken Ends of the Bone, which if scraped off prevents the Regeneration of the Callus. But if that Substance be left upon the Bone, and defended from the Air with Powder of Myrrh, Gum Sarcocol, or the like, that Mucilage is then condenfed into a Membrane, which by degrees becomes a Callus as tough as Leather, and afterwards hard and more compact than the Bone itself. If therefore the elementary and nutritious Particles are thus fent in all Directions from within outwards by the proper Vessels, even in Parts so compact and rigid as the Bones themselves after Fractures. it is therefore evident that the fame Matter is continually propelled the fame Ways in the healthy Body; and if the Bones thus continually grow and are supplied with nutritious Matter, how much more readily may we conceive all the other Parts to be nourished and increased in the same Manner?

6 If the Hands are washed very clean, and then rubbed pretty-hard upon one another, there will appear innumerable conical or sharp-pointed Particles or Scales like Threads, which Children usually call Worms. If again these Scales are dissolved in Water, they deposit an oily Liniment, and leave nothing but the mere Scales alone, namely, the Productions or Extremities of the small exhaling Veffels. You will also perceive very large white Scales of this Nature, if after washing the Hands clean with Soap and rubbing them, you put on Gloves lined with black Velvet, and wear them next to the Skin for eight or ten Days: and this is an Experiment of Lewenboec, a Man of infinite Patience and Industry, to whose Writings we are much indebted. The Scurf or Scales which are continually scraped off in combing the Head, are nothing

more

more than little Particles of the Cuticle abraded or cast off; infomuch that I can readily believe, that as Serpents cast their Skin yearly, and as Silkworms deposit the same sour times in a Year, so the human Species deposit or cast off their Cuticle every Month,

\$ 477. From hence we may likewise understand, that the Increase of Bulk in the Body, with respect to the whole Habit, in large, sleshy, and fat I People, does not proceed from an Increase of the Solids, but only from their having larger Cavities filled with stagnating and accumulated Humours, by which they are extended; for which reason Fatness is troublesome, weakens and infringes the Circulation. Hence therefore the Physician ought carefully to distinguish betwixt Repletion and Nutrition, since the one strengthens and thickens the Vessels, while the other weakens, relaxes, and extends them.

that his Body shall exceed twice its former Weight, without the least Addition made to any of the solid Parts, as we see in the Leucophlegmatia or Dropsy of the Veins, and in Obesity. A Manwho has undergone a mercurial Salivation, so as to evacuate almost his whole Body, after he is recovered and supplied with good Aliments, easily gains his former Bulk. And by Exercise or Labour his Body may be reduced again to a State of Leanness. But yet in none of these Cases are the Muscles themselves enlarged. The Heart of the Plowing-Ox is light, and composed almost entire-

ly of muscular Fibres; but if the same Animal is put to fatten, the Heart will weigh three times as much, being buried in Fat; and if the same Heart be boiled in Water for a confiderable time, the Heart will be found nothing larger than at first it was in its lean State, because the Fat is melted down and discharged. A lean Hog, whose Muscles lie fo close to the Skin, that they are easily wounded by a flight Puncture through that Integument, does yet arrive to fo great a Degree of Fatness by six Months Feeding, as to be three, four, five, or even fix times his former Weight, when at the fame time his Muscles and Vessels are rather less than before; but the Bulk arises entirely from the Lard interposed betwixt the Muscles and the Skin. But although the Animal is thus increased in Bulk, yet neither are the Vessels increafed in Number, nor the Bones in Length; nor are the Nerves, Cartilages, or any other folid Parts enlarged or augmented one Grain in Weight; nor is the whole Mass of Blood augmented in the least: but, on the contrary, the fanguiferous Veffels are rather compressed and diminished, and the Mass of Blood itself lessened in proportion as the Fat is augmented. Thus in a lean Person, where it is easy to open the median Vein, if the same Person grows Fat, that Vein can be scarce found or perceived, not from changing its Situation but from being compressed or diminished. In Oxen and in Hogs which have fattened to the last Degree, there is very little Blood. Physicians ought therefore to be mindful that lean People eafily support Bleeding, but that Phlebotomy in fat People is generally prejudicial.

In lean People there is Abundance of Juices, and the sanguiserous Vessels or those of the first Order are very large; but in fat People a great

Part

Part of the Blood being turned into Oil, supposes a Diminution of the sanguiserous Vessels and their Juices. Hence Fatness obtunds all the Faculties, renders the Person unsit for Action, and hastens the Period of Life. But in order to preserve Health entire, the Body is to be exercised with frequent Labour that it may never be oppressed with Fat. Lean Animals which are generally imagined to be weak, are nevertheless the strongest and most active.

§. 478. From hence also the Reason is evident, why the Fabric of our folid Parts is not diffolved 1 by their contained Juices? as also from whence it happens that our Machines are capable of fubfifting fo long in a Capacity for Motion 2? whence it is that the Nerves 3 being any way destroyed, the Nutrition of the Part to which they belong is then abolished? and also why the Nourishment of the Part is likewife abolished when an Artery 4 is destroyed? why in an Embryo 5 there are no folid Parts! very few in a Fœtus, and why they abound most in very old Age; infomuch that in the last, the Nerves, Tendons, Arteries 6, and other Receptacles become cartilaginous and then bony; of come or deferve more of orthanding then

of mere Earth, which is so closely connected by the Intervention of Water and Oil without any alcaline Salt, that only Fire or a long continued Putrefaction can separate its Parts from each other. From hence we may easily understand why the Motion and Flux of our Juices does not dissolve and waste the solid Parts of our Bodies. Nor ought the D d 4 Strength

Strength of Cohesion in the Solids to seem new or incredible, fince from Water and Earth arise solid Bodies, which cannot be again diffolved by Water. Clay that is well dried turns into a volatile Dust which offends the Eyes of the Traveller; but the fame Clay being mixed up with Water, formed into Balls and flowly dried, does at length turn into a hard Stone, by passing gradually through the several Degrees of Fire; after which it is no longer capable of being diffolved in Water, notwithstanding that was the Medium by which the Particles were gradually brought into more close Contact, fo as at length to assume the Hardness of a Stone: for when the Water is expelled both in the Cricks and in the folid Parts of Animals, they both of

them are then a mere folid Earth.

<sup>2</sup> We very often fee Men of ninety Years old capable of fustaining all the Functions of Life, which would almost feem incredible to a Person who confiders what violent and perpetual Motions our foft and tender Machines fustain during the Space of fo many Years. I know that this is nothing new nor furprifing with the Generality of Men; but when the Philosopher of old was asked What was the most wonderful? he wisely answered, That which the Vulgar did not admire; for we are furprised at unusual things, while we neglect those as infignificant which occur to our daily Observation. notwithstanding they deserve more of our Attention and Admiration, in proportion as they are perpetual Benefits which we enjoy. This Activity therefore in some very old Men is the Consequence of their Vessels remaining pervious or moveable, but this is effected by the Intervention of Water or Moisture, which is transfused betwixt the Fibres; to which add the Oil abounding in our Aliments, and fwimming in large Quantities under the Form

of Cream, lubricating and mollifying the folid Fibres and Vessels, so as to facilitate their Motions. But when these smallest Vessels concrete together by the Actions of Life, the oily and watery Juices are expressed from betwixt the Fibres, and being confumed, they cause that kind of Death which follows from mere old Age, namely, from the too great Refistance of the folid Fibres and Vessels overpowering the Force of the Heart. If a Person could prevent the smallest Vessels from concreting into Fibres, he might render Life perpetual; but this is what no Mortal can effect. It is an Axiom which we in general experience to be true, as well in Animals as in Vegetables, that those which arrive foonest to their full Growth, survive the shortest time: whereas, on the contrary, those Animals or Persons who are a long time in growing, these continue a long time in the fame State, and are also a long time in decaying. Even these three Stages of Growth, Duration, and Decay, generally take up an equal Number of Years. Those Animals which grow for the Space of twenty Years, continue in their full Strength until the Age of forty, from which time their Forces decline, and hardly continue beyond the fixtieth Year. great Climacteric Year, namely, the fixty-third. is composed of the three Stages of Life before-mentioned, containing each twenty-one Years. Those who are addicted to hard Labour in their younger Years do not live fo long as they otherwise perhaps might.

It is found by Experience, that after a Nerve has been tied in a living Dog or destroyed in the human Body by some Disease, an Insensibility and Wasting follows in those Parts to which that Nerve was distributed; namely, because Nutrition is carried on in the smallest Vessels, which as far as we

can perceive must be the Nerves themselves, whose Trunks being compressed, their Branches will collapse. But this kind of Wasting is called a Wi-

thering in the Parts.

From the Arteries arise small Vessels, no larger than the nervous Threads themselves, which smallest Arteries are destined to the like Office of immediately carrying on the Business of Nutrition. We know not of any Reason why the Artery should not divide into Branches equally minute in the other Parts of the Body as in the Brain itself; but yet such small Arteries must be destitute both of the Power of producing Motion and Sensation, since both these Faculties result only from the Encephalon. But Nutrition is principally carried on in these smallest Arteries, which convey Juices next in Subtlety to the Juice of the Nerves themselves.

The Fœtus which does not exceed the Size of an Ant, is nevertheless visibly composed of a Head, Brain, Eyes, and protuberant Limbs; and has doubtless also the Vessels of the Brain, the Vessels of the Skull, and all the more fubtle Parts, without which those larger visible Parts could not be produced; yet the whole is no more confiftent than a Mucus, and dissolves like a Fluid with the least Touch, much less is there the Appearance of Bones. But we are used to distinguish Solids from Fluids only by our Senses, and the Smallness of the Force which is required to feparate their elementary or In Water that has had a constituent Particles. Grain of Pepper infused into it for some Time, no one would imagine or suspect that it contained any thing folid, when at the fame time it is every where filled with small Fish: and even the sharpest Vinegar viewed by the Microscope in the Summer-time, appears full of white small Eels frisking about,

about, which a Man of a sharp Sight may even perceive with his naked Eye without the Help of a magnifying Lens. We ought not therefore to conclude, that those are wanting in the Fœtus which our Senses discover in the Adult, but not in the Fœtus, in which they retain the Confiftence of a Mucus. But in that State of the Animal the Solids bear the least Proportion of all, being perhaps a tenth Part of the Animalcule which weighs a Grain; and from that Time the Proportion of the Solids to the Fluids continually increases, fince fome Parts of the latter are perpetually converted into a folid Nature. In a Collection of Foetus's which I posses, the Skull in the first Month is a mere membranous Bag; but in the ninth Month it is partly membranous and partly of a bony Nature. And even for some time after the Birth, a great Part of the Bones is mere Cartilage, and pervaded with almost an infinite Number of small But the fame Bone in Process of Time is fo compressed by the Pulsations of the Arteries in the Periosteum with the Pressure of the adjacent Muscles, that they are at length condensed and compacted into Bones of the greatest Hardness. After this the Ligaments also by degrees become tough and inflexible as Cartilages, and the Cartilages themselves interposed betwixt the Vertebra turn into Bones. I have feen all the Ligaments of the Vertebræ, Neck, Back, and Loins, with the Os facrum concreted into one continued Pillar of Bone, and the Tendons themselves changed into bony Skewers; the Septum and Cavities of the Heart with the falciform Sinus and other Membranes were offified, namely, by expressing the Fluids which interpose betwixt the folid elementary Particles. But the Origin of Solidity in the Bones generally proceeds from a Point or Center, and extends

extends itself towards the Circumference, as we may plainly perceive in the Bones of the Forehead; but by degrees the Vessels are enlarged, and the smallest of them compressed so that they concrete

by their Emptiness.

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We have a notable Instance of this Truth in the Bone of the Stag's Heart, or the Offification formed in the Beginning of the Aorta, which is continually found in this long-lived, active, and fwift-footed Animal, when killed after long chafing. Some Physicians have fearched for this Bone in those Stags which Princes breed in their Parks. without being so successful as to find it; for it is only to be met with in those which are old and have been frequently hunted; and in these it is generally formed by the Palpitation of the Heart which precedes Death. The Arabian Physicians ridiculously attributed high Virtues to this Bone. fuppoling it to be capable of rendering a Person equally active and long-lived with the Animal from whence it is taken; which is much the fame as to recommend the Feet of a Hare to a Person whose Business it is to run. In short, such bony Callosities and bony Productions arise in all Parts of the Body; and the Feet of Letter-Carriers are armed with a kind of Soles of the Confistence of Horn.

§. 479. From hence likewise we may understand the Number 1 and Variety of Orders there are in the Circulation of our Juices? with the Proportion and Difference of the Effects 2 which from thence follow? as also how we may solve the Problem 3 concerning the Time in which all the Humours may pass in one Course through the Heart? with other Questions

Questions of the like Nature, which to a hasty and inconsiderate Person may appear easy, but will be found very difficult or altogether impossible to be resolved by a Person who thoughtfully makes the Attempt.

Altogether as many as there are different Parts in the Body; for every Part has its peculiar Circulation, as is evident from the particular Fabric of each; nor can the Nature of each Circulation be understood, unless we have a thorough Knowledge of the minute Structure of each Part. For the Velocity of the circulating Humours varies in Proportion to the Distance of the Part from the Heart. according to the Elasticity of the Vessels, their Angles or Incurvations, &c. In general, the Circulation is the fwiftest when the Blood passes through the Heart to and from the fanguiferous Veffels of its muscular Fabric, which may be performed within Part of an Hour (§. 187.): for in fo short a time does the Heart look red and again become pale from its being filled with and emptied of its Blood; and in fo short a Space of time at least is there an Ounce of Blood transmitted through the smallest Vessels of the Heart. But that this is the Capacity of the vascular System in the Heart is demonftrated by injecting Water fo as to fill the cardiac Arteries, and after expressing the same, comparing the Weight of the Heart with what is weighed before, the Difference of which will be equal to an Ounce. From this great Velocity it is that the Blood of the Heart is extremely thin and inclined to Putrefaction. But the Circulation is flower in the other Parts in proportion as they are more remote from the Heart. Next to the Heart the Circulation is quickest in the Pericardium. which is perpetually agitated by the Heart itself and

and Motion of the Diaphragm. We read in the Works of Peyerus, that if the Pericardium is wiped dry in the living Animal, there would be a continual Succession of Drops of the Humour which it separates from the Blood. In the Lungs the Circulation is finished within the third Part of a Minute or fomething less (§. 208.); for we count almost ten Pulses to one Respiration. After the Lungs the Velocity of the Circulation is greatest in the bronchial Vessels, next in the Intercostals, and then in the Brain. In general, the Circulation is quickest in the vital Organs, but something different in each; whereas in all other Parts of the Body it moves flower according to particular Circumstances. Hence a Dropfy first shews itself in the Feet and Legs, &c. Among the Viscera the Blood moves flowest through the Liver (§. 337, 350.), but the flowest of all in the Body through the Bones, in which it is probable that the Circulation hardly compleats its Courfe within a Month.

Namely, both to destroy and to nourish the Parts; and therefore the Heart, in which the Circulation is the most rapid, is of all Parts the soon-

est destroyed, and the soonest repaired.

First, Harvey, and afterwards De Back and Wallis attempted to determine the Space of Time in which all the Humours of an animal Body might pass through the Heart. Their Calculations were raised without much Difficulty. Suppose, for Instance, there are two Ounces of Blood expelled at each Contraction of the Heart, since it appears that each of its Ventricles is capable of receiving such a Quantity, and evacuating themselves entirely at each Systole; and suppose again the Pulsation of the Arteries to be 3600 times in an Hour, and that the Quantity of Blood in a healthy Man is sixteen Pounds; it will from thence easily appear,

appear, that these fixteen Pounds of Blood must have passed twenty-eight times through the Heart within the Space of an Hour. But this was not the Question; for in this Manner is determined the Quantity of Blood passing through the Heart in the Space of an Hour, but does not ascertain the Time in which the whole Mass of Blood in the Body may pass through the Heart, excepting what exhales; nor does it determine the Time in which the fame individual Ounce of Blood will again return to the Heart from whence it passed; nor does it inform us of the time in which any Part of the Mass of Blood circulates through any particular Membrane or Viscus, or what the particular Velocity of the Blood is in each Veffel; for these are Questions to which no one will answer, unless he is perfectly acquainted with the Fabric of each Vifcus and the Power of every individual Vessel. But these Particulars I am afraid will never be exactly known: for Example, to determine the time in which a Portion of Blood passes through a Finger. we ought to be acquainted with the Resistance which the Artery makes to the Heart, with its Area or Diameter, &c. But suppose every necessary Circumftance to be determined in a Man who is fleeping, if he does but awake and move his Finger. more Blood will pass through than before, and still more if he increases the Motion of it. Circulation of the Blood is therefore in fome Parts very quick, and in others very flow; and therefore an Ounce of Blood passes frequently through the Heart, before another Ounce returns once from the Heart to the Extremities.

§. 480. The Order or Method of Science next requires us to treat first of Sleep and Vigilance;

gilance; but as in these we always meet with Rest or Exercise of the external and internal Senses, with what relates to them, therefore we are naturally led by the Course of Things to enquire into the external Senses; and in the first place we are to treat of the most simple, common, and general Sense, which we call the Touch or Feeling.

Half the Life of Man is spent in Sleep; and during that Space he is not Man, but a mere Automaton. During the other Part of Life which is fpent in Vigilance, those Motions which are carried on merely as in a Machine in the time of Sleep, are not so well performed, notwithstanding he is conscious of them. But in a found Sleep, every Part which is governed by the Influence of the Mind, together with the Will, Memory, Reafon and Imagination itself cease; for those who contend that these Actions take place in Sleep, such confound dreaming with Sleep, namely, a Mixture of Vigilance with Sleep (§. 590, and 599.) But there is another Difference which comes betwixt Sleeping and Vigilance, and this is a fort of Medium betwixt both: namely, in Sleep the Motion of the Heart remains, while the Respiration, Digestion of the Aliments, with the Secretion, Perspiration, and Heat of the Humours go on; only the Senses are at Rest, namely, the Sight, Touch, Hearing, and voluntary Motions. Since therefore Sleep is defined to be a Privation of these Senses, we ought first to consider them, in order to obtain first a perfect Knowledge of Sleep. But among all the Senses, the Touch is the most ample, all the rest being only certain Species of feeling

Thus to hear, is to perceive the Vibration or Percussion of the external Air, drove in a tremulous
Motion through the Fenestra ovalis; to smell, is
to perceive the Changes or Impressions made by
odoriferous Particles themselves upon the Papilla
of the olfactory Nerves: but the Touch or Feeling is the Perception of the Changes made throughout the whole Surface of the Body by the Application of any Object; and therefore that most ample and obvious of the Senses which we call the
Touch, ought to be first considered.

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